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STUDY OF MONKEY, APE, AND HUMAN MORPHOLOGY AND PHYSIOLOGY
RELATING TO STRENGTH AND ENDURANCE

PHASE IV

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William E. Edwards

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April 1965



6571st Aeromedical Research Laboratory
Aerospace Medical Division
Air Force Systems Command
Holloman Air Force Base, New Mexico

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STUDY OF MONKEY, APE, AND HUMAN MORPHOLOGY AND PHYSIOLOGY
RELATING TO STRENGTH AND ENDURANCE

PHASE IV

THE MUSCULOSKELETAL ANATOMY OF THE THORAX AND BRACHIUM OF AN
ADULT FEMALE CHIMPANZEE

William E. Edwards

FOREWORD

This is the first in a series of four papers concerned with the musculoskeletal system of the thorax and upper extremities of the chimpanzee and the squirrel monkey. This study was conducted during the period 1961-1963 by William E. Edwards, under Contract AF 29(600)-3466, Project 6892, Task 689201. The program was monitored by Major James E. Cook, Veterinary Services Division, ARRV.

The author wishes to acknowledge the assistance of Mr. T. Erskine Clarke in the phase of dissection and of Mr. Robert Halferty for help with the photographic work. The writer is also indebted to Dr. Edward M. Burn of the South Carolina State Hospital, Dr. Daris R. Swindler of the South Carolina Medical College, Lt. Col. Hamilton H. Blackshear, USAF, MC, Major Robert H. Edwards, USAF, MC, Major James E. Cook, USAF, VC, and Major Clyde H. Kratochvil, USAF, MC, of the 6571st Aeromedical Research Laboratory for their helpful cooperation and encouragement in this study.

Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.



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ABSTRACT

The left thoracic and brachial musculature of a young-adult female chimpanzee is described and illustrated with the accuracy of detail plus clarity made possible by the photo-etching process. Other data are depicted graphically by section drawings. Comparisons with data from the literature on other chimpanzees, apes, humans, and non-hominoid primates are also provided, with emphasis on quantitative aspects.

TABLE OF CONTENTS

| | Page |
|---|------|
| 1. INTRODUCTION | 1 |
| 2. HISTORY OF RESEARCH PRESENTED HERE | 2 |
| 3. DESCRIPTION OF SUBJECT | 2 |
| 4. PROCEDURE OF STUDY. | 4 |
| 5. Description of Muscle Morphology | 7 |
| A. Muscles of the Shoulder Girdle | 7 |
| B. Muscles of the Shoulder. | 11 |
| C. Muscles of the Arm | 13 |
| 6. EVALUATION | 19 |
| REFERENCES | 21 |
| APPENDIX - Figures 1 through 19 | 25 |

THE MUSCULO-SKELETAL ANATOMY OF THE THORAX AND BRACHIUM
OF AN ADULT FEMALE CHIMPANZEE

1. INTRODUCTION

Before the Christian era, non-human primates were long employed as substitute subjects for anatomical studies because of the taboo against dissection of cadavers -- a taboo not significantly violated until the studies of the Alexandrian Herophilus, approximately 300 B.C. By the time of Galen (c. 130-200 A.D.), some of the anatomical subjects were apparently anthropoid apes (which likely ranged at least somewhat more widely at that time) but most were catarrhine monkeys, such as the tailless "Barbary ape" (Macaca sylvana) of North Africa (Yerkes and Yerkes, 1929, pp. 3-7). Thus Vesalius learned thirteen centuries later that Galen's errors for man tended to be correct for "apes."

Through the Middle Ages and into the Renaissance -- when the human studies of da Vinci (1452-1519) and Vesalius (1514-1564) were conducted -- general prohibition of human dissection, despite some permitted exceptions, encouraged some of that minority of physicians unwilling to rely upon the work of Galen to use other primates as substitutes.

The first identifiable ape to be dissected with detailed anatomical descriptions still extant was the chimpanzee ("a Pygmie") reported upon by Tyson (1699). Since the work of Tyson, scores of primatologists have published studies of ape anatomy. The chimpanzee has been the object of a plurality of these studies because of its relative accessibility and its similarity to man morphologically and in other respects (Schultz, 1936; Yerkes, 1943, pp. 3-8; Hooton, 1946, pp. 39-44).

It might seem, therefore, that no further anatomical studies of the chimpanzee are needed. However, many studies are limited to brief -- and thus necessarily incomplete -- verbal descriptions, while with only partial exceptions the papers which have presented drawings have shown the voluntary musculature only diagrammatically or vaguely and imprecisely. "Dependable sources of anatomical information...on the chimpanzee are few and wholly inadequate. There is no convenient atlas and no text which is complete and reliable. Sperino's Anatomia del Cimpanzè (1897) includes an account of the muscular, respiratory, gastrointestinal, and nervous systems, but it is based almost entirely on the dissection of a single female whose age was estimated as two years" (Yerkes, 1943, p. 282).

2. HISTORY OF RESEARCH PRESENTED HERE

On June 14, 1961, an Aeromedical Research Laboratory adult female chimpanzee died, and the writer decided upon his arrival a month later that the formalin-fixed cadaver would be used for detailed, quantitative studies of the musculature of the upper extremities -- during extra hours, since this was not part of the strength-testing project for which he had been employed. The anatomical study seemed significant, however, because the factors determining any differences in strength between chimpanzee and man would almost surely include anatomical differences.

Studies of the thoracic and brachial musculature were initiated August 4, 1961, and continued intermittently until September 10. Various factors necessitated postponement of the resumption of intensive study until March, 1963, and its completion until June, 1963.

3. DESCRIPTION OF THE SUBJECT

The subject, ARL Chimpanzee #133, was a young adult female chimpanzee of unidentified race (for geographic distribution of species, see Coolidge, 1933, pp. 34-35), with an estimated age of 15 years at the time of death. Extensive gangrene following an accident to her right forearm necessitated euthanasia under anesthesia. Her last recorded body-weight, on May 19, 1961, was 89.5 pounds.

Immediately after death, the chimpanzee was injected with a 10 per cent formalin solution through the arterial system, but without individual treatment of the left upper extremity. In the subsequent autopsy, the gangrenous right arm and all viscera were removed, with transection of the rib-cage and such muscles as pectoralis major (Fig. 1). Much of the head was removed with the brain, with resulting loss of the cephalad portion of muscles traversing the cervical region. From the time of the autopsy, June 14, to the initiation of dissection, August 4, the cadaver was kept in a refrigerated locker at approximately 2° C., as continued to be the case between intervals of dissection and study until mid-September, 1961.

Panometric data procured immediately prior to dissection include the following, in millimeters:

| | |
|--|-----|
| Cephalad surface of acromion tip (13 mm. medial to lateral border of brachium) to distal tip of lateral epicondyle | 308 |
| Cephalad surface of acromion tip to distal tip of medial epicondyle | 326 |

| | |
|--|---------------------|
| Distal tip of medial epicondyle to distal tip of ulnar styloid process | 254 |
| Distal tip of lateral epicondyle to distal tip of radial styloid process | 268 ⁺ 15 |
| Medial surface of epidermis at tip of medial epicondyle to opposite lateral surface at elbow | 96 |
| Medial surface of epidermis at ulnar styloid process to lateral surface at radial styloid process | 56 |
| Distal tip of radial styloid process to distal tip of digit I | 103 ⁺ 5 |
| Distal tip of ulnar styloid process to distal tip of digit V | 161 ⁺ 4 |
| Length of the fleshy portion of the digits from the base of the cleft between the digits ¹ | |
| I (from I-II) | 42 |
| II (from I-II) | 121 |
| II (from II-III) | 80 |
| III (from II-III) | 95 |
| III (from III-IV) | 98 |
| IV (from III-IV) | 82 |
| IV (from IV-V) | 90 |
| V (from IV-V) | 68 |

Circumferences

| | |
|---|-----|
| Through axilla and over shoulder 63 mm. medial to lateral surface of brachium | 425 |
| Brachium at inferior (caudal) border of axilla on dorsal surface of body (30 mm. inferior to inferior border of axilla on ventral surface) | 265 |
| Middle of brachium | 263 |
| Brachium 63 mm. proximal to distal tip of medial epicondyle | 238 |
| Elbow across lateral and medial epicondyles | 261 |

¹These measurements of the length of digits are not precise (-3 or 4 mm.) because of the impossibility of extending fingers fully without damaging the specimen.

| | |
|---|-----|
| Antebrachium 50 mm. distal to distal tip of medial epicondyle | 256 |
| Middle of antebrachium | 229 |
| Distal end of antebrachium across styloid processes | 172 |

Circumferences at the middle of the second phalanges²

| | |
|----------------------|----|
| I (proximal phalanx) | 42 |
| II | 55 |
| III | 64 |
| IV | 54 |
| V | 42 |

Measurements of the cranium

| | |
|---|------|
| Bi-orbital breadth | 84 |
| Middle of superior border of supraorbital torus to prostion | 97.5 |
| Upper facial height (nasion-prostion) | 68 |
| Bi-zygomatic diameter (10 mm. posterior to anterior border of orbits) | 106 |
| Prostion-gonion | 128 |

Some active decomposition of the specimen began soon after death, and grossly apparent autolysis continued until the study was completed. Even during the first month of study in 1961, the muscular, tendinous, and fascial tissues and even the arteries, veins, and nerves of this subject developed a progressively uniform gray coloration.

Formalin was reapplied in South Carolina and the specimen was kept refrigerated at a temperature slightly above freezing, but the process of deterioration was never entirely arrested. In the spring of 1963, during which the remainder and vast majority of the study was carried out, to the problem of uniform coloration was added that of some softening of muscle tissues.

4. PROCEDURE OF STUDY

As the dissection of the chimpanzee (preceded by that of the squirrel

²These five measures of the fleshy portions of each digit were much more significantly affected by dessication and other changes than the other measures in the 50 days between death and study.

monkey) proceeded in August, 1961, the writer prepared fairly detailed verbal descriptions, including extensive measurements. It was soon recognized that written descriptions and measurements were entirely inadequate, as has been confirmed by a subsequent survey of pertinent literature, which reveals that much undoubtedly meticulous study is relatively worthless because of the limitations of verbal descriptions and the validity, at least in anatomical studies, of the adage concerning a thousand words versus one picture. Therefore, the writer prepared diagrammatic sketches and then careful drawings to clarify photographs, but he decided that even the latter were quantitatively too imprecise.

It was finally decided that only very precise drawings could show the form, size, and relationships of the musculoskeletal system entirely satisfactorily, and the most feasible way to produce these was by the process of photo-etching, in which an India ink drawing is made directly upon a photographic print, which is then bleached out. A brief survey of the literature reveals that a somewhat comparable technique has been utilized in the preparation of Grant's An Atlas of Anatomy (1947), for which muscle outlines were traced by the use of photographs and a viewing box.

Several variants of the photo-etching process were tested. The one selected involves the use of "Kodak Illustrators' Special E" double-weight enlarging paper, with the print fixed in plain sodium thiosulphate (100 gm. to 320 gm. of water). In drying, no ferrotyping is used; the surface of the print can be made more receptive to the ink by rubbing with talcum powder. After the drawing is completed, the picture is immersed for 90 seconds in a solution of 10 gm. of potassium permanganate and 10 gm. of sulphuric acid in 2250 gm. of water. The resulting bronzed print is then washed gently for 5 minutes and "cleared" in a solution of 40 gm. of sodium thiosulphate plus 10 gm. of glacial acetic acid in 160 gm. of water. Although more experimentation may effect further improvement, the writer still finds that there is generally some running of the ink and smudging, requiring laborious application of white paint and India ink after the bleaching.

At the Aeromedical Field Laboratory, by the time the photographs were printed, parts of the specimen had in some cases been removed, and vital anatomical landmarks and lines of separation between parallel muscles were often confusingly absent in the photographs. Thus a more precise and complete photographic record was sought. Photographs in color as well as black-and-white were helpful but far from entirely adequate, and by 1963 such photographs would have been virtually useless for analysis of tissue boundaries because of the remarkably uniform coloration previously noted. After some experimentation, it was found that application of a purple ("Venus Copying") indelible pencil directly on the wetted tissue yields just the proper amount of pigment absorption by the tissues for clear markings and photographic reproduction of tendon boundaries and fiber alignments (although diffusion of the pigment leads to gradual blurring of the marked lines over a period of hours).

It might seem that this combination of techniques would make the preparation of excellent, accurate photo-etchings both very simple and quite rapid; unfortunately, such is not the case. Not only do many of the essential features fail to show up with sufficient clarity on the photographs, but, especially after imperfect preservation, it is extremely difficult to distinguish types of tissue as well as tissue boundaries and fiber directions for a large proportion of the features.

Typically in the current study (1963), after dissection and arrangement of all structures in their proper form for the illustration and after subsequent meticulous drawing on the tissues by indelible pencil, 12 to 25 photographs were taken for a single figure. From enlargements of these photographs, the one best showing the features and their relationships was chosen and printed in multiple copies, whereupon the specimen was further studied and discussed by the writer and his assistant. With frequent comparison with the specimen, the artist-assistant then prepared a rough draft, which was checked and errors noted by the writer. A second draft was next prepared by the assistant and checked and corrected by the writer to provide the basis for the final draft by the assistant and the writer. Even when this final draft was, as in some cases, the fourth version, and had required most of the time of the writer and the assistant for some four days from the start of the dissection for the single illustration, it generally manifested a few flaws requiring correction. Subsequent rechecking with the specimen and thorough comparison with associated drawings has been found to be worthwhile, for errors have thereby been discovered long after a drawing had been considered complete. But such errors have been relatively few and, with only one or two exceptions, minor, so it is hoped that any published mistakes, which have escaped detection, are at least rare and insignificant.

Some improvements in procedure were made during the course of the work to date, as noted. Another involves greater reliance upon drawing pens with retractable "needles" which make lines of constant width easier to draw instead of exclusively upon crow-quill pens -- still best for the finest lines. These drawing pens facilitated transfer in style of representation from dashed lines for both muscle fiber and tendon (earliest drawings of squirrel monkey) to tendon only (Figs. 1-4) to medium solid line for muscle fiber and fine solid line for tendon (Figs. 5-12). A further improvement in the process of preparation was provided by spraying (with precautions to avoid damage to the technician's lungs) with an acrylic resin ("Krylon Crystal Clear Spray Coating") after the drawing was bleached, to protect the softened ink from smudging and peeling. Identifications are typed directly on the plastic-protected drawing, which after application of another plastic film has label lines applied in ink or pencil (or cut by scalpel where solid black is crossed) and is given a final layer of plastic spray.

In the future, selective staining of anatomic components will be tested when tissue differentiation is poor. After further experimentation, the writer also plans to use pencils for the drawings on the

photographs; development of a suitable procedure for use of pencil should result in faster and more readily modifiable drawings. Whether pen or pencil is used, it is hoped that the bleaching process can be improved to obviate the presently necessary painting and drawing over the damaged lines.

5. DESCRIPTION OF MUSCLE MORPHOLOGY

A. Muscles of the Shoulder Girdle

Pectoralis major. This most superficial muscle of the chest -- although covered by platysma in much of its most cephalad portion -- is large and flat (Figs. 1, 2, 7, and 8). It takes origin from the medial two-thirds of the anteroinferior (ventroposterior) border of the clavicle, from the sternum and first six costal cartilages, and from the aponeurosis of the external oblique muscle (Sonntag, 1924, p. 181). As Sonntag noted, differing from the other apes and man, the clavicular portion seems entirely continuous with the costo-sternal part. From this broad fan-shaped origin, it converges to insert upon the crest of the greater tuberosity of the humerus and along the lateral lip of the very deep bicipital groove. Most distally, its heavy tendon is shared with deltoid (Figs. 7 and 10); perhaps this is the condition referred to by Fick (1925, p. 121), who observed that much of the clavicular portion inserted not on the humerus but on the tendon of the deltoid. The horizontal sectioning of this muscle made prior to this study may be seen in Figure 1 and is depicted in greater detail in Figure 16, where the maximum thickness shown is 22 mm.

Because of the earlier damage to pectoralis major, detailed comparisons with the human condition are not possible. Yet, since the action of this muscle upon the humerus is a major component of muscular activity involved in arboreal climbing and brachiating and is thus more crucial to the chimpanzee and requires the application of more force than in man, obvious adaptations might be anticipated. At least two such adaptations are evident. First, the muscle is proportionately much thicker in the chimpanzee; all else equal, muscle force is proportionate to muscle thickness. Second, the area of insertion, 37 mm. to 118 mm. below the proximal end of the humerus, extends appreciably further down the 324.5-mm. humerus (measured radiographically) from the shoulder-joint than in man; all else equal, exertable force is proportionate to the distance of the point of application of force (muscle insertion) from the fulcrum (joint). For comparison, Stewart's chimpanzee manifested an insertion 23 mm. to 67 mm. below the proximal end of the humerus (1936, p. 161).

Pectoralis minor. This flat, roughly triangular muscle of moderate size lies deep to pectoralis major and -- though its origin was damaged

before the specimen was studied -- likely arises from the sternal ends of the second or third to fifth ribs, as in man. The tendon of insertion of pectoralis minor crosses the tip of the coracoid process superficial and slightly cephalad to it, with the tendon's center-line passing within 12.5 mm. of the distalmost tip (Figs. 8-12). It inserts into the heavy capsule over the anterosuperior aspect of the head of the humerus, broadening to some 12 mm. just before fusing into the capsule. The insertion is located directly beneath the most lateral tip of the acromion; a third of the insertion's breadth extends laterally beyond the acromion. A more superficial layer of tendinous capsule -- entirely continuous with the tendinous slip accessory to the common tendon of origin of biceps and coracobrachialis, to be described, and as noted by Fick (1925, p. 122) -- is penetrated by the tendon of pectoralis minor immediately lateral to the coracoid process. This superficial sheath fuses with the deeper one a short distance lateroinferior to the tendon of pectoralis minor, approximately 6 mm. from the nearer border of the tendon in the middle third of the distance from the center of the coracoid tip to the pectoralis minor tendon's insertion 42 mm. laterally. The tendon's smallest transverse section (4.8 x 2.2 mm.) occurs 23 mm. from its insertion.

Fick's (1925, p. 121) chimpanzee specimens manifested origins from the second and mainly the third and fourth ribs, similar to Stewart's (1936, p. 163), but others varied in origin considerably (Chapman, 1879, p. 54; Sonntag, 1924, p. 182). Insertion of pectoralis minor in the chimpanzee is not usually upon the coracoid process, as in man, although such insertions have been observed. In rare examples in the chimpanzee, insertion is both on the coracoid process and into the capsule of the shoulder-joint; but a capsular insertion alone, as in the present subject, is most common (Sonntag, 1924, p. 182). In the lower primates, the insertion is similarly into the capsule or restricted to the lesser or greater tuberosity (Hill, 1953, p. 63); among the platyrhine genera Cebus and Callicebus it is also inserted into the capsule (Hill, 1960, p. 33), as it largely is in Ateles, where its insertion is fused to that of pectoralis abdominis (Hill, 1962, p. 393).

In the gorilla, pectoralis minor and pectoralis quartus both take costal origins and coracoid insertions (Raven, 1950, p. 41 and Pl. 29). A similar condition has been reported as an anomaly in the chimpanzee (Sonntag, 1924, p. 182).

Trapezius. On the dorsal surface of the thorax, this large, flat muscle, bilaterally of trapezium outline, extends superficially across most of the upper back (Figs. 3 and 4). From its extensive, partially aponeurotic origin along the midline of the back, the muscle converges to insert upon the spine of the scapula, the acromion, and the lateral third of the clavicle (Figs. 1-5, 8, and 10). As shown in cross-section in Figure 13, it manifests the surprising thickness of 26 mm. (slightly more than an inch) where originally transected in the mid-to-lower cervical region.

Despite its greater mass in the chimpanzee, it is very similar to the human trapezius (Vrolik, 1841, pp. 18 and 27; Champneys, 1871, p. 178). Sonntag (1924, p. 174) contends that in the chimpanzee it may fuse with latissimus dorsi caudally, as in the specimen of Schuck (1913, p. 375), but at least in the present specimen only the sponeurotic tendons were very firmly adherent in the small area of overlap, with trapezius more superficial (for comparable observations, see Fick, 1925, p. 119).

Latissimus dorsi. Most of the remainder of the back is covered by this muscle, even more extensive than trapezius and more caudally located except for the small area where it is deep to trapezius near the middle of the back's midline (Figs. 1, 4, and 5). It arises from the posterior layer of the lumbodorsal fascia, which is attached to the spinous processes of the lowest thoracic and the lumbar vertebrae, the posterior surface of the sacrum, and the crest of the ilium. Accessory digitations were observed on the eleventh, twelfth, and thirteenth (last) ribs, although some studies have reported costal origins not quite so caudal (Sonntag, 1924, pp. 174-175; Fick, 1925, p. 119). As in all primates, there is no scapular origin (Hill, 1953, p. 63; Hill, 1957, p. 31). Triangular in form, it converges as it crosses the posterior wall of the axilla behind the brachial plexus. It converges further to pass beneath coracobrachialis as a flat and relatively narrow tendon of insertion -- 26 mm. wide and 0.6 ~ 1.1 mm. thick, 35 mm. from the center of the insertion, and 27 mm. wide at the insertion, measured perpendicular to the tendon borders. This tendon attaches to the medial lip of the deep bicipital groove of the humerus, slightly medial to the tendon of insertion of coracobrachialis and immediately lateral to that of teres major (Figs. 6, 8, and 10-12). As shown in cross-section in Figure 14, latissimus dorsi has a maximum thickness of at least 20 mm.

Levator scapulae. Under trapezius, arising from the transverse processes of the cervical vertebrae, this broad and fairly thick muscle inserts fairly extensively upon the border of the scapula from 13 mm. lateral to the medial angle (this point here defined as that with the smallest radius of curvature) to a point 71 mm. distant measured along the vertebral border; the inferior edge is 17 mm. cephalad from the center of the scapular spine's junction with the vertebral border. Rhomboideus overlaps upon the caudal end of the deeper levator scapulae for 26 mm. The superior border of levator scapulae inserts at the same point and immediately superficial to the superior border of serratus anterior's insertion on the cranial border of the scapula.

In different chimpanzees studied, the origin of levator scapulae varies widely from the atlas and axis (Champneys, 1871) to the first five cervical vertebrae (Sutton, 1884, p. 76; Virchow, 1909, p. 144), with two (Gratiolet and Alix, 1866, p. 139) to five slips of origin, which in some cases may "remain separate to near the insertion" (Sonntag, 1924, pp. 175-176).

The writer would offer the rather obvious suggestion that in the chimpanzee the levator scapulae functions primarily to elevate the neck and head rather than to raise the scapula, as in man, so the terms "origin" and "insertion" -- terms presently employed very little by many anatomists anyway -- might better be reversed from their usage for man. Consideration of relatively greater gravitational resistance in the generally more nearly pronograde ape would also account for the massiveness of the muscle relative to that of man, especially in the great apes because of geometrical similitude (Edwards, 1963a).

In many of the haplorhines (tarsier and higher primates), levator scapulae is represented by the anterior and posterior atlanto-scapulares (Hill, 1955, p. 37); this separation, noted for other chimpanzees by Sonntag, is likely reflected in the partial differentiation of the muscle in the present specimen (Fig. 9).

Rhomboides. This muscle, with the important function in arboreal locomotion of fixing the vertebral border of the scapula, is very thick but otherwise shows an origin and insertion quite similar to rhomboideus major and minor in man, except for the previously noted overlap with levator scapulae. From the superficial surface, the muscle is readily separable into approximately equal halves (Fig. 5), but deeper than approximately half-way through the muscle's thickness, this cleavage becomes no more marked than that between other bundles of muscle fibers. The ventral surface of rhomboideus reveals a line of change in fiber direction fairly near the cranial border of the muscle (Fig. 9), suggesting a dichotomy more like the general condition in man.

In most lower primates (Hill, 1953, p. 62) and in many other catarrhines -- especially the apes, including the chimpanzee (Schuck, 1913, p. 390; Fick, 1925, p. 119), though Champneys (1871) described an example of marked division in a chimpanzee -- there is no clearly distinct rhomboideus minor (Hill, 1957, p. 31), nor even in man in some cases (Hollinshead, 1951, p. 88).

Serratus anterior (serratus ventralis). This muscle is primarily inferior to the scapula and in all but its scapular portion almost completely covered by latissimus dorsi. Because of its significant climbing and brachiating functions, including pronating and depressing the scapula, this mostly lateral and dorsal chimpanzee muscle is broader and thicker than in man and arises by digitations from the lateral costal surfaces not only as far caudally as the eighth or ninth rib, as in man, but to the penultimate twelfth rib (Figs. 5, 9, and 11).

Sonntag (1924, p. 184) reports the origin of serratus anterior caudally as far as the eleventh rib and Miller (1952, p. 199) only to the tenth. But Stewart (1936, p. 189) found the origin extending to the twelfth rib on one side and inserting on the entire vertebral border

of the scapula, with the heaviest insertion marked by fairly thick tendinous attachment to the inferior angle. Reportedly, all primates manifest cervical as well as costal origins, with the exception of the tarsier, apes, and man (Miller, 1932, p. 11).

Serratus posterior. Limited observations of this muscle revealed no particularly notable features (Fig. 5).

Cleidomastoid and omocervicalis. Lacking their superior portions, these muscles are shown in Figures 5 and 10 arising and inserting, respectively, on the clavicle, consistent with their description by Stewart (1936, pp. 146-149) for the chimpanzee and other apes, although not with Miller's (1952) description. Omocervicalis in man is "usually completely absorbed by the trapezius and has lost its identity as a separate structure" (Miller, 1932, p. 9), but it occurs more fully developed as a rare anomaly (Chapman, 1879, p. 54).

B. Muscles of the Shoulder

Deltoideus. Very similar to the human muscle, this triangular muscle, the largest of the shoulder muscles, weighing 210 gm. during the first interval of dissection (1961) in this probably slightly dehydrated specimen, covers the point of the shoulder and portions of deeper muscles, including much of infraspinatus and all of teres minor. It arises in an essentially contiguous manner from the spine of the scapula, the acromion, and the clavicle. As shown in Figures 3 and 4, there is also a relatively small but heavy accessory slip which takes its origin from the heavy fascia covering infraspinatus, as has also been observed by Sonntag (1924, p. 182) and Fick (1925, p. 121), the latter having described it as "a strong distal bundle from the infraspinatus attached to the upper edge of the teres major." The deltoid converges to insert by means of heavy tendons upon the anterolateral surface of the humerus in an area approximately one-fourth to one-half of the way from the proximal to the distal end of the humerus, between the origin of the lateral head of triceps and brachialis posteriorly and the more distal portion of the insertion of pectoralis major anteriorly (Figs. 1-5, 7, 8, and 10). The horizontal section of this muscle approximately half-way between the origin and insertion reveals its great thickness, to 2.7 cm. in this subject (Fig. 15).

Supraspinatus. Immediately underlying most of the more lateral portion of trapezius and occupying the superomedial half of the scapula, above the spine, this roughly triangular muscle is covered by fairly thick fascia with varying fiber alignment (Fig. 5). Supraspinatus takes origin from the supraspinous fossa, which it alone occupies, and

inserts upon the uppermost facet of the greater tuberosity of the humerus by a relatively narrow tendon which extends laterally beneath the acromion.

Infraspinatus. This muscle, much larger than supraspinatus, arises from much of the surface of the infraspinous fossa which it occupies, and inserts upon the greater tuberosity in a relatively small area immediately between the insertions of supraspinatus and teres minor. Despite close similarity to the human condition in all the features noted above, the chimpanzee infraspinatus differs by being divided in its inferior (caudal) half into nearly equal halves by a fairly marked central sulcus almost parallel to the scapular spine, resulting in essentially two heads of origin, medial and lateral. This sulcus is marked by a moderately thick tendinous sheet in a plane which at the dorsal surface of the muscle is fairly perpendicular to the dermis. Heaviest near the inferior (posterior) angle of the scapula, the tendinous sheet gradually thins until it is no longer visible on the muscle surface some 78 mm. above the angle; some 7 mm. above the end of this septum (and some 95 mm. from the insertion of infraspinatus upon the humerus), the sulcus virtually disappears as well, with clear representation above this point only by a difference in muscle fiber alignment. This inferior septum is undoubtedly a tendon of origin, associated with the concentration of origin along the spine, axillary border, and inferior portion of the fossa of the scapula (Beddard, 1893, p. 187). The lateral portion of the muscle manifests muscle fiber alignment markedly oblique to the sulcus and to the fibers of the medial portion (Figs. 3-5, and 7). The muscle is covered by a moderately heavy fascial sheath, half of which is illustrated in Figure 4.

Teres minor. This "small round" muscle arises from the middle and upper portions of the axillary border of the scapula and inserts into the lowermost facet of the greater tuberosity of the humerus, immediately distal to the insertion of infraspinatus. The muscle is heavier than in man, has a markedly broader insertion, and is divided into two portions with an obliqueness of fiber direction rather similar to that of infraspinatus (Figs. 5 and 7).

In strepsirrhines (lower primates), teres minor is incompletely differentiated from infraspinatus (Hill, 1953, p. 63), while in the Cebidae, "no teres minor is differentiated" (Hill, 1960, p. 33). Others have regarded teres minor as having evolved as a gradually differentiating scapular slip of the deltoid (Parsons, 1898, p. 723).

Teres major. This very thick muscle arises from the inferior angle by a moderately heavy tendon as well as from the inferior portion of the axillary border of the scapula and is separated from teres minor by the long head of triceps as teres major passes across the posterior wall of

the axilla to the anterior surface of the humerus. There it inserts by a broad tendon of irregular length upon the medial lip of the bicipital groove, in its proximal half immediately medial to and beneath the tendon of latissimus dorsi -- from which it is largely separated by a bursa -- and, in its more distal portion, immediately medial to and beneath the tendon of insertion of the short head of coracobrachialis (Figs. 3-5, 11, and 12).

Subscapularis. Arising across the ventral surface of the scapula, this thick muscle inserts upon the lesser tuberosity of the humerus. Quite similar to its form in man, subscapularis is divided into some six major segments; as shown in Figure 11, the muscle fibers within each segment are aligned obliquely to the sulci between segments. These sulci are only rather faintly developed, but, as indicated by somewhat broader lines in the drawing, are more marked than the corresponding furrows and planes of cleavage between the fiber bundles, which are 1.5-3.0 mm. in diameter in this muscle. Most of the fascia covering the ventral surface of subscapularis is quite tendinous in appearance, but the fascia is nevertheless quite thin, with fibers aligned in as many as three directions at a single locus, as evident in the inferomedial portion of the fascial sheath illustrated in Figure 11. For a somewhat differing description, see Fick (1925, p. 121).

C. Muscles of the Arm

Biceps brachii. This large, hemicylindrical muscle occupies approximately the anterolateral quadrant of the brachium (Figs. 1-11). The long head arises from the supraglenoid tuberosity of the scapula by a long and relatively slender tendon, which traverses the capsule of the shoulder joint and extends down the bicipital groove, which is very deep and relatively broad, consistent with the role of biceps as the chief flexor of the antebrachium at the elbow in climbing and brachiating. In this subject, neither the one accessory head noted by Howell and Straus (1931, pp. 2-3) on one side nor the two accessory contralateral heads of their specimen were evident. The short head arises from the coracoid process by a broad, heavy common tendon with coracobrachialis and also more distally by muscle fibers tightly adherent to the tendon sheet separating biceps from coracobrachialis (Fig. 10). This tendon sheet might also be considered a common tendon, but it is properly assignable to coracobrachialis, primarily because it extends distally on the superficial surface of coracobrachialis 24 mm. beyond to its area of fusion with biceps.

Separation between the two heads continues distally far beyond the point where the two come into intimate contact with one another approximately 100 mm. from the coracoid process, only a third the length of the humerus (Fig. 8); complete fusion is not achieved on the deep

surface before 68 per cent or on the superior surface until 80 per cent of the total length of the fleshy portion of the muscle, some 220 mm., has been traversed.

Distal to its belly mid-point, tendons begin to develop within the fleshy portion of biceps, mostly on or near the deep surface, and become progressively heavier and more numerous toward the insertion (Fig. 17), which is primarily upon the tuberosity of the radius and very secondarily by the weakly developed *lacertus fibrosus* to the fascia over the flexor surface of the forearm. Although Howell and Straus (1931, p. 2) report that the *lacertus fibrosus* was "quite . . . well-marked," Pira (1913, p. 325) reported that among various studies of the closely related gorilla only he and Sommer had observed a *lacertus fibrosus*, and Sonntag (1924, p. 184) generalized that it is "reduced in the apes" relative to man, which accords with present observations.

More detailed quantitative data on general dimensions and location of tendons is provided by Figure 17.

Although this subject had only two biceps heads, as in Homo, Macaca, and Tarsius, a third head (accessory slip of origin) from the humerus has been frequently reported for chimpanzees as well as other apes, while gibbons may even manifest a fourth head (Hill, 1955, p. 38). The area of fusion of the two heads in this subject, much more distal than in man, is fairly typical of other chimpanzees and many other haplorines, but more proximal than in some of the other catarrhines, such as Macaca and Cercopithecus, in which it is not achieved until near the insertion (Hill, 1955, p. 38).

Coracobrachialis. This flat muscle of irregular shape is almost entirely covered by biceps and pectoralis major. As noted, it arises by a broad tendon in common with the short head of biceps, but the much thinner medial third of this tendon is more properly assignable to coracobrachialis alone (Figs. 1, 6, and 8-12). Distally, the common tendon of origin gradually becomes broader and, more rapidly, thinner. Extending from the medial third of the tendon at the coracoid process is a thinner tendon paralleling the common tendon, medial to it, and also continuous with a tendon sheet separating the fleshy portion of biceps from coracobrachialis; it also extends laterally beyond the common tendon, with which it is distally contiguous but not fused, and in all three parallel and continuous areas is assignable to coracobrachialis (Figs. 10 and 19). There is also illustrated (Figs. 9-12) a tendinous extension from the lateral side of the coracoid process toward the acromion which might be considered an accessory common tendon of origin of coracobrachialis and biceps. In the specimen as drawn, this tendon is quite thick and is 6 mm. wide, but this is primarily an artifact of dissection, largely through expansion of the foramen penetrated by the tendon of pectoralis minor for a better view of this tendon. So this reinforcing tendon of origin is in actuality only a portion of the

locally two-layered capsule of the shoulder-joint, and it has been more fully described in the section on *pectoralis minor*.

The fleshy portion of this flat and broad but only moderately thick muscle extends as high as the distal end of the prominent coracoid process and rapidly broadens to insert proximally along the mid-line of the bottom of the deep, broad bicipital groove, and even somewhat more laterally as the insertion proceeds distally and the groove becomes shallow and terminates. This insertion extends in the same line to a point approximately 60 per cent of the distance down the total length of the humerus and is above and immediately lateral to the tendons of *latissimus dorsi* and *teres major* (Figs. 10-12). The musculocutaneous nerve pierces the muscle, but unlike the human pattern, the nerve traverses a cleft which largely divides the muscle into a large, more lateral, proximal portion and a longer but more attenuated distal portion. These two portions represent the "profundus (brevis)" and "medius" heads described and figured by Howell and Straus (1931, pp. 2-3 and Pl. 1). But the two intimately conjoined portions of the muscle in the writer's subject manifest nothing comparable to the 18-mm. hiatus between insertions in their specimen, while the right arm of their subject completely lacked the shorter head. Sonntag (1924, p. 184) states that the short head is absent in apes and man, which is confirmed by Hill (1957, p. 31), who asserts that the musculocutaneous nerve simply pierces the medial head in apes and man but passes between this head and profundus in monkeys and strepsirrhines. It appears likely that the absence of the more proximal portion on one side and the marked separation at the nerve's penetration on the other side of the Howell and Straus specimen both represent fairly rare anomalies. But despite interpretations in part based upon an atypical subject by Howell and Straus while that of Sonntag and Hill was presumably based upon a larger number of subjects, it seems to the writer more probable that the short (brevis) head has not been eliminated in man and the apes but has shifted distalward and broadened, as implied in the identifications of Howell and Straus.

The right arm of the Howell and Straus (1931, p. 2) subject revealed an "anomalous superficial portion (of coracobrachialis which) took origin in common with, and upon the medial side of, the short biceps origin from the coracoid. It continued entirely superficial to all nerves and muscles of the brachium, except the dorsoepitrochlearis, to its insertion upon the medial epicondyle. It was slender but sharply defined, the distal half being nonmuscular and weakly tendinous." Such extreme development of this part of coracobrachialis is also apparently very rare, although others have noted comparable but less well-developed heads in the chimpanzee, despite its general rareness among platyrhines and catarrhines (Hill, 1957, p. 31). Sonntag (1924, p. 184) contends that this superficial portion, which he terms the "long part," is among apes and man "only present in the Orang and Chimpanzee," where it "runs to the internal intermuscular septum and dorso-epitrochlearis." There seems little doubt that the small slip of coracobrachialis in the specimen here reported is homologous to this superficial portion, despite its

more distal origin from the medial superficial tendon of the main body of coracobrachialis and its insertion by very thin and only slightly tendinous fascia -- precluding any significant contractile function -- upon the fascia of dorsoepithrochlearis and the fascia on both sides of the sulcus between the medial and long heads of triceps (Fig. 9). It seems to conform closely to the 1-cm.-wide coracobrachialis slip reported by Fick (1925, p. 122).

From the foregoing discussion, it seems evident that coracobrachialis is extremely variable between different primate species, individuals of the same species, and even sides of the same individual primate (Wood, 1867, pp. 45-55). Despite such apparent inconsistencies as its "powerful" development in the gorilla (Sommer, 1907, p. 197), this variability quite surely reflects, the writer would suggest, the relative insignificance of the coracobrachialis -- especially of its accessory superficial portion -- among the higher primates, as is confirmed by the moderate size of the muscle and by the generally small size of the superficial part when present.

Some of the dimensions and relationships of coracobrachialis to neighboring features are clarified in Figure 19.

Brachialis. This broad, flat muscle arises from the anterolateral surface of the distal 65 per cent of the humerus and extends over most of the corresponding anterolateral portion of the arm, with its medial half largely covered by biceps. The medial intermuscular septum, which in the chimpanzee is less marked than in man and near its superficial border much more nearly parallels the dermis, provides some additional area of origin for brachialis muscle fibers, the most superficial of which are indicated by the few slightly overlapping muscle lines in Figures 10 and 12. Brachialis inserts upon the coronoid process and tuberosity of the ulna (Figs. 1-5, 7, 10, and 12). As might be anticipated because of its exclusive function of flexing the forearm in this largely arboreal animal, brachialis is a very thick muscle which is similar to the human homologous organ except for its lesser development medially and greater thickness laterally, consistent with its lack of an origin on the medial side of the deltoid in this specimen -- although at least one exception to this condition was discovered in a chimpanzee dissected by Sonntag (1924, p. 184) and another partial exception in the specimen of Howell and Straus (1931, p. 2). Unlike a presumably large proportion of chimpanzee brachialis muscles (Howell and Straus, 1931, pp. 2 and 24) and those of some other haplorhines (Hill, 1955, p. 39), in this specimen brachialis was not partly separable longitudinally into a pars medialis and a pars lateralis.

In many other catarrhines, such as the rhesus monkey (Hartman and Straus, 1933, p. 132), the origin of brachialis extends appreciably higher on the humerus than in the chimpanzee and man. In the lower primates and tarsier, it may have an extra head from the surgical neck

of the humerus, although usually it is similar to the condition in man (Hill, 1953, p. 64; Hill, 1955, p. 39). *Brachialis* is relatively more extensive and complex in most more generalized placentals, such as insectivores and rodents (Parsons, 1898, p. 728).

Despite the variations noted in comparisons with other specimens, it may be observed that interspecifically and probably intraspecifically *brachialis* is the most constant of the primate brachial flexors (Howell and Straus, 1931, p. 28).

Dorsoepitrochlearis (latissimo-epicondyloideus). This long, fairly slender, flat-fusiform muscle extends down the arm as the most superficial muscle on the medial aspect of the brachium (Figs. 1, 6, and 8-12). As in most haplorhines (Hill, 1955, p. 37), it arises from the base of the broad band of heavy tendon of insertion of *latissimus dorsi* where the tendon fuses with the fleshy portion of that muscle. In this very unusual muscular relationship, therefore, there is in a sense a common tendon of insertion of *latissimus dorsi* and of origin of *dorsoepitrochlearis*. The fleshy belly of the muscle is restricted exclusively to the proximal 60 per cent of its length; a heavy, broad band of tendon comprises the distal 40 per cent and inserts after some fiber convergence upon the medial aspect of the medial epicondyle -- and at least in this specimen apparently only very secondarily into the distal end of the medial intermuscular septum, cited as the area of insertion for all apes by Sonntag (1924, p. 185), although the insertion in this specimen closely approximates that of the gorilla reported by Raven (1950, p. 43). In the present specimen, the length of the fleshy portion is 125 mm. and the total length, including the tendon of insertion, some 210 mm. It is 10 mm. thick at its thickest point and 35 mm. wide at its widest. Further data on the form and dimensions of *dorsoepitrochlearis* in this chimpanzee are provided by Figure 18. For comparison, "In Tschika, this muscle is about 4 cm. broad on the left side and 5 cm. broad on the right side; in Tschego they were only 2½ cm." (Fick, 1925, p. 122); both of Fick's subjects were apparently adults. In an earlier study by Fick (1895, pp. 313-314), no dimensions were given, but the muscle apparently differed somewhat from the present specimen, for (unlike an orangutan with a tendinous origin described in the same paper) the origin was fleshy and a few bundles inserted upon the triceps tendon.

Since *dorsoepitrochlearis* is a climbing muscle, which functions "in heaving the body upwards to a position previously gained by the hand" (Hill, 1957, p. 31), it is characteristic of all apes and monkeys, and in many, such as Ateles (Hill, 1962, p. 392), it is very similar to Pan. Likewise, its absence in man -- except for homologous fascia or the ligament of Struthers and rare, more extensively developed anomalies (Champneys, 1871, pp. 180-181) -- is not surprising, despite its good development in the primarily non-arboreal drill (Sonntag, 1924, p. 185).

Raven (1950, p. 43) has suggested that dorsoepitrochlearis "may be derived from the long head of triceps. They are parallel throughout, part of the origin is from the scapula, a strong aponeurotic sheet connects their tendons of insertion, and the nerve supply is from rami of the same branch of the radial nerve." The present writer feels that such suggestions, however speculative of necessity at first, are urgently needed to change anatomy from that which is still primarily a descriptive science to an equally interpretive one, with determination of the events of morphological evolution and, at a deeper interpretive level, the factors accounting for such events (see also Davis, 1955, pp. 34-35). In this case, however, neither the parallelism nor the innervation seems convincing. The scapular origin and aponeurotic sheet are characteristic of the gorilla in contrast to other primates as a response to the much greater difficulty of achieving sufficient strength for climbing, caused by the enormous size of this partially arboreal primate and the resulting demands of the principles of geometrical similitude (Edwards, 1963b). The suggested interpretation of Raven therefore appears to be another example of a fallacious generalization based upon a single -- and in this instance atypical -- case. It should be noted, however, that Hartman and Straus (1933, p. 133) had also come to the conclusion that dorsoepitrochlearis "is really a part of the triceps complex that has become secondarily connected with the *m. latissimus dorsi*." It is also interesting to observe that more than a century ago dorsoepitrochlearis was widely interpreted as a portion of *latissimus dorsi* (Champneys, 1871, p. 180). For more adequate phylogenetic interpretations, the presence and form of dorsoepitrochlearis in the widest variety of species should be considered; in the lower primates, for example, it arises not from *latissimus dorsi* "but from two heads from opposite sides of its fascial sheath" (Hill, 1953, p. 63) and, in lemurs, at least, "continues beyond the olecranon far down into the forearm fascia" (Miller, 1932, p. 22). It also appears in a wide variety of non-primates, including, for example, the dog (Parsons, 1898, p. 723).

Triceps brachii. This powerful extensor of the forearm is the largest in the arm of this chimpanzee -- although the flexors combine for greater total mass -- and occupies the entire posterior surface of the humerus. The lateral head arises from the posteromedial surface (apparently slightly more medial than in man) of the humerus, extending proximally as high as the area immediately medial to the insertion of *teres minor*; it also arises from the proximal portion of the lateral intermuscular septum. The medial head takes its origin from the medial and anteromedial surfaces of the humerus (extending proximally almost as high as the lateral head) and from the entire length of the medial intermuscular septum. Except for some rotation about the humeral circumference, the lateral and medial heads are very similar to those of man, but the long head is more markedly distinct. It is much heavier than in man, and originates from a larger portion of the axillary border of the scapula -- from the border of the glenoid cavity to a distance of some 55 mm. inferomedially, approximately 40 per cent of the distance to the inferior angle. Running parallel with the humerus, the three

heads undergo incomplete fusion distally and insert broadly upon the dorsal aspect of the olecranon process and on both sides of the olecranon by an aponeurotic extension into the antebrachial fascia, as in the gorilla (Raven, 1950, p. 43).

One difference from man associated with the medial head in this chimpanzee is the relative lack of development of the medial intermuscular septum, as noted previously; another is that the ulnar nerve does not, as in man, traverse most of the distal half of the medial head approximating the septum, but instead occupies a shallow, two-thirds-enclosing groove some 1 cm. medial from the septum, approximately as in the gorilla (Raven, 1950, Pl. 36). The present writer would suggest that, despite the greater development of brachialis in the chimpanzee, the relatively smaller medial portion of brachialis, noted previously, has less need for a heavy accessory septum for origin. The ulnar nerve more precisely parallels the muscle fibers of the medial head in apes than in man, so its groove protection -- in addition to protection by the tendon of dorsoepitrochlearis -- is provided at little "cost" in semi-arboreal forms in which injury to nerves of the upper extremity are both more frequent and more deleterious to survival than in man. The superficial head of coracobrachialis, apparently generally only vestigial in chimpanzees and occurring only as rare anomalies in man, may likewise have retained in the chimpanzee the function of protecting underlying nerves and blood vessels, just sufficient to justify its survival in greatly reduced form.

6. EVALUATION

The reason for the lack of any prior study of comparable nature -- despite the fact that the chimpanzee, closely related to man, is likely man's closest extant analog -- has become abundantly evident to the writer upon completion of the present study. This first of the series of four studies has alone required more than a thousand man-hours.

On the other hand, it is felt that much has been accomplished by this research. During the past few decades, and especially during the last five years, the study of non-human primates has accelerated rapidly, especially for the apes, with application to problems from the understanding of man's ancestry of forty million years ago to space-flight of the future. The present paper apparently provides the most detailed and precise gross anatomical study of a major portion of a non-human primate specimen to date.

Nevertheless, even within the present scope of study, many additional observations, measurements, and drawings are needed for such a single specimen to be studied in a truly definite fashion. Furthermore, marked contralateral variability has been noted by a number of primatologists for the chimpanzee; for example, Miller (1952, p. 230) notes that at

least ten of the some two hundred pairs of muscles manifested marked right-versus-left differences in her pygmy chimpanzee. Finally, as with man, chimpanzee inter-individual variability in the musculo-skeletal system is high, so the anatomy of this species cannot be at all adequately defined from one or two specimens.

So it must regrettably be concluded that, significant though it is hoped the present study will prove to be, the "general and inclusive description of chimpanzee anatomy . . . drawn from competent dissection of an adequate number of normal mature specimens of each sex ~~which is~~ urgently needed" (Yerkes, 1943, p. 282) is satisfied only in very small part by the present study.

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APPENDIX

Figures 1 through 19

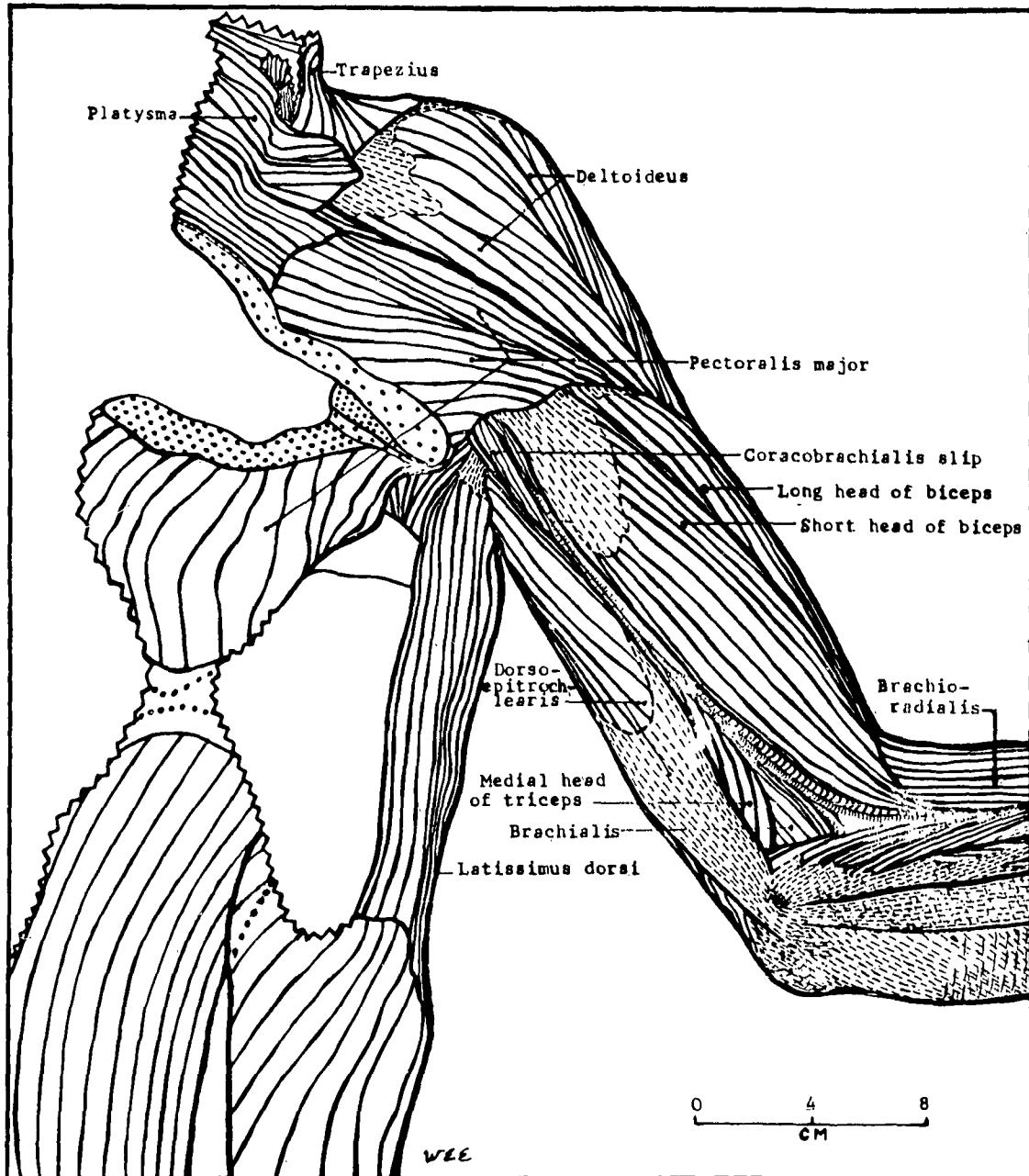


Figure 1

Anterior (Ventral) View of Left Half of Thorax and Brachium, with Dermis Removed

Note the irregular sectioning of pectoralis major and the hiatus between pectoralis major and latissimus dorsi -- defects resulting from earlier autopsy.

Note the representation of muscle belly by solid lines and tendon by dashed lines.

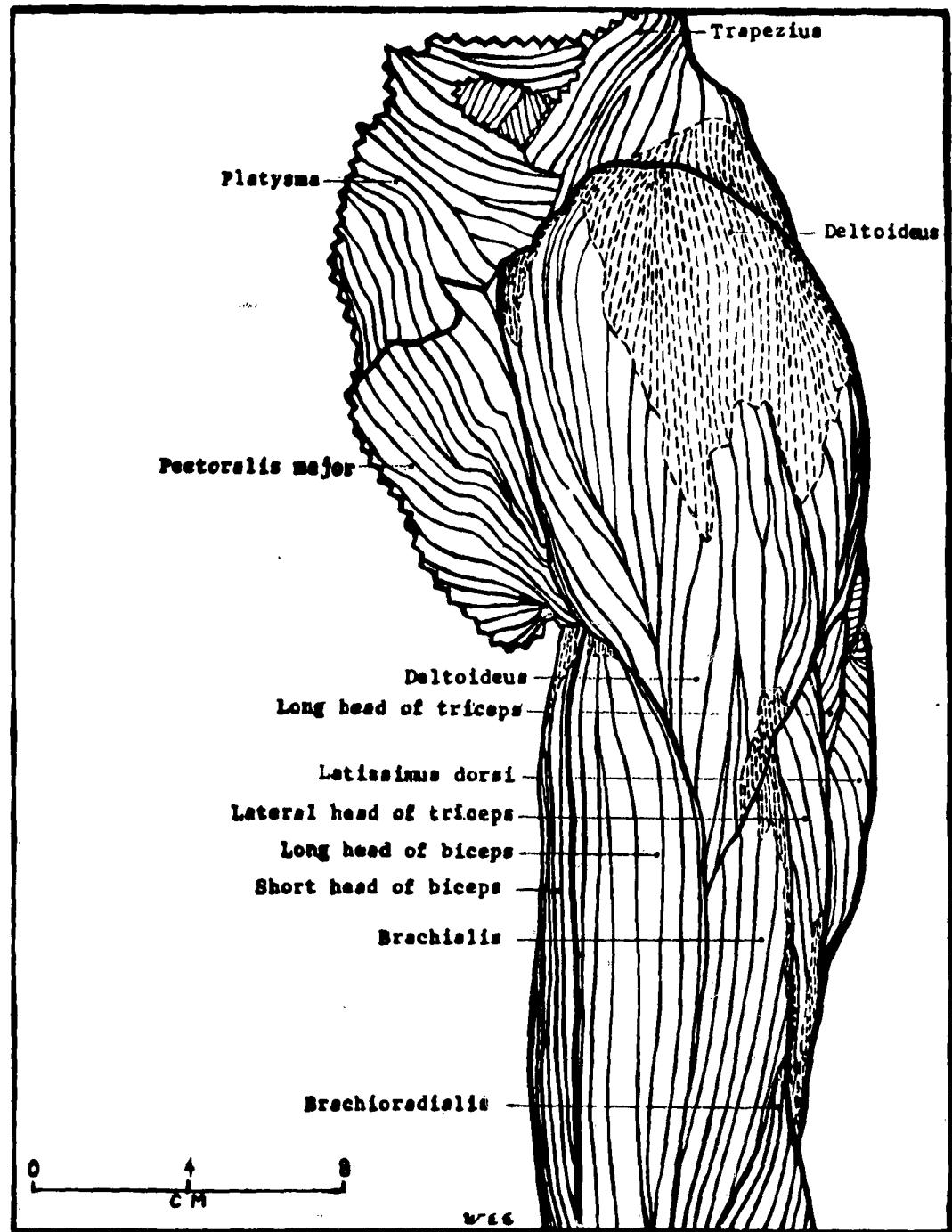


Figure 2

Anterolateral View of Left Brachium, with Dermis Removed

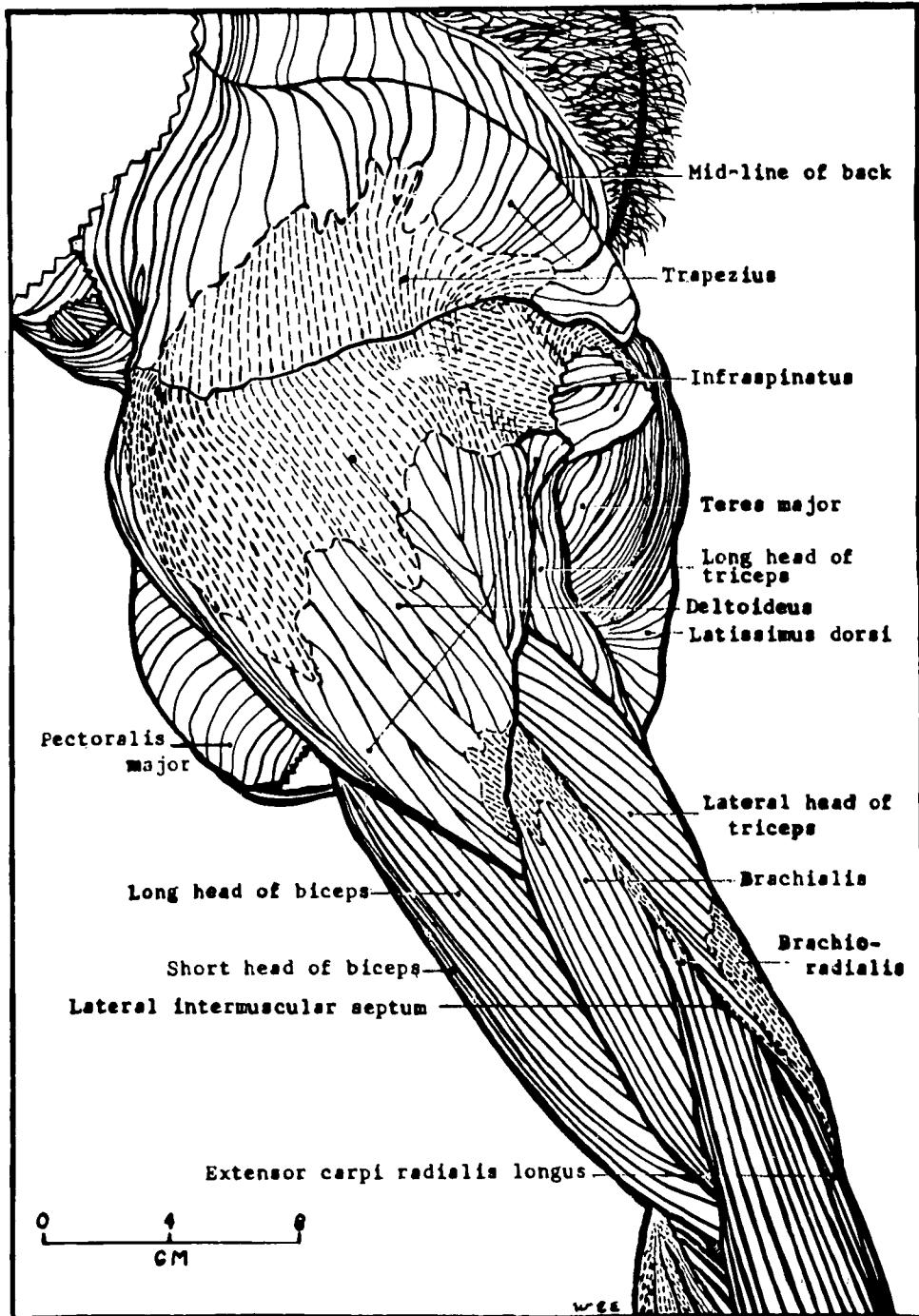


Figure 3

Superolateral View of Thorax and Brachium, with Dermis Removed

Note dermis removal extends slightly to the right of the dorsal mid-line.

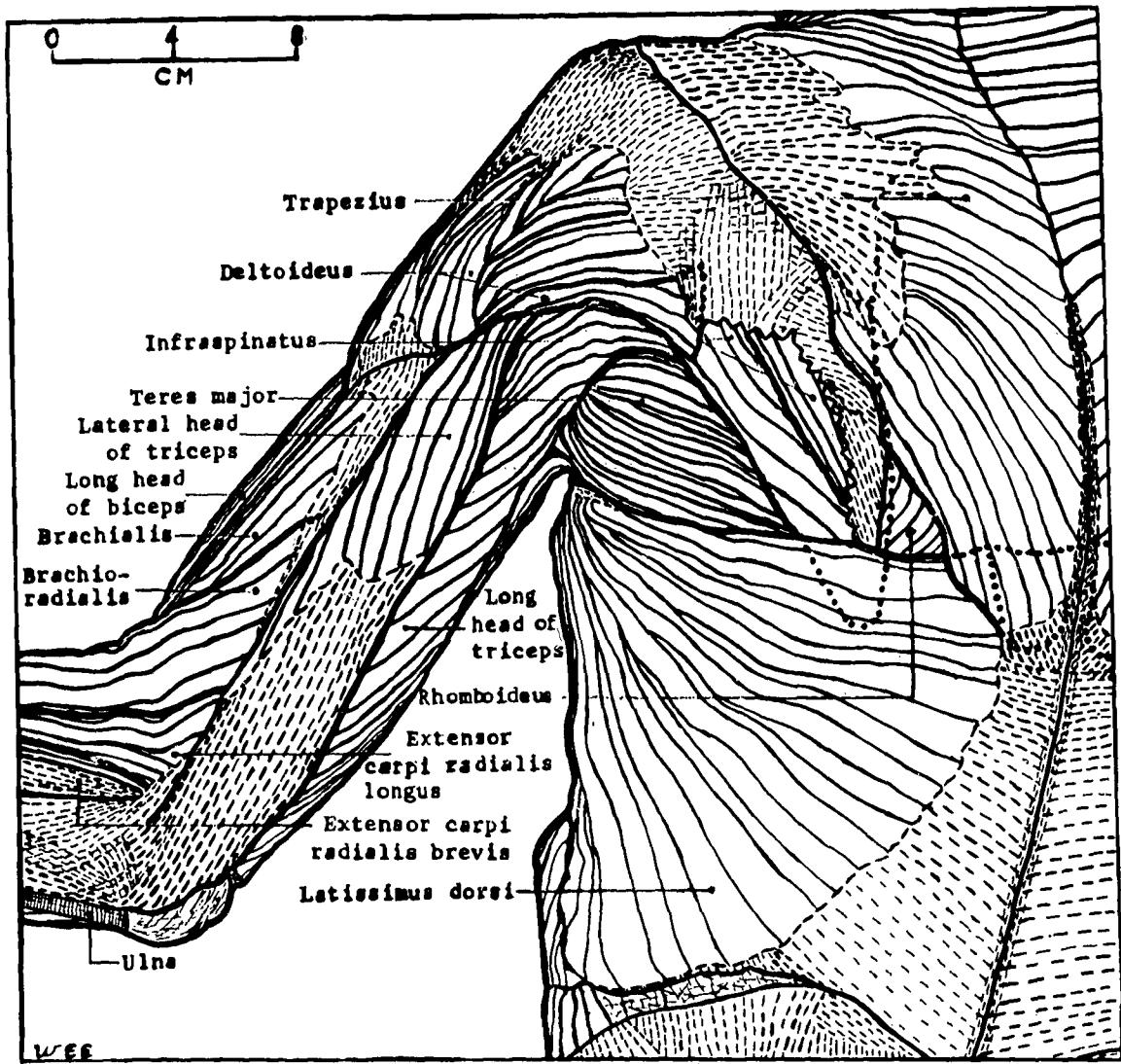


Figure 4

Posterior (Dorsal) View of Left Half of Thorax and Brachium, with Dermis Removed

Note the accessory head of deltoideus arising from the superficial fascia over infraspinatus.

Note also that, unlike man, part of the ulna is visible at this stage of dissection, covered only by fairly thick fascia.

Note the dotted lines, indicating the approximate borders of the scapula and of the tendon of origin of latissimus dorsi.

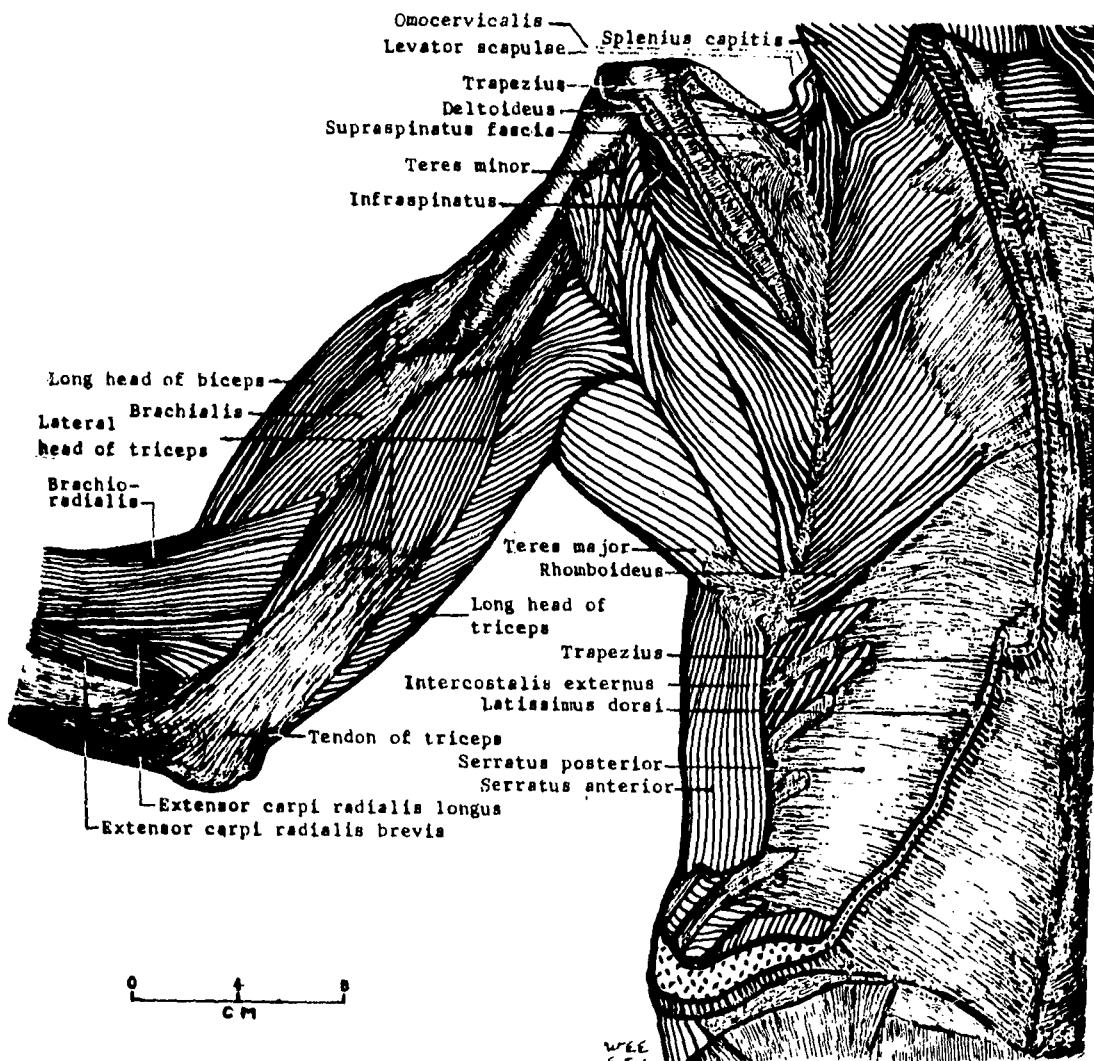


Figure 5

Deeper Layer of Musculature of Left Half of Back and Shoulder

Note symbols are identical to those of Figures 1-4, except fine lines have replaced dashed lines to represent tendon and fascia.

Note trapezius, latissimus dorsi, and deltoideus have been removed, except for narrow fringes of origin and insertion tendon and belly.

Note the relatively narrow insertion of infraspinatus and relatively broad insertion of teres minor on the humerus.

Note the central sulcus of the inferior (posterior) half of infraspinatus and the varied muscle fiber alignment in this muscle, as in teres minor.

Note the varied fiber alignment of the fascia covering supraspinatus.

Note the fissure largely dividing rhomboideus into two fairly equal portions.

Note the thick tendon of insertion for much of the inferior portion of serratus anterior on the inferior angle of the scapula, where it is fused to the thickest tendon of origin of teres major.

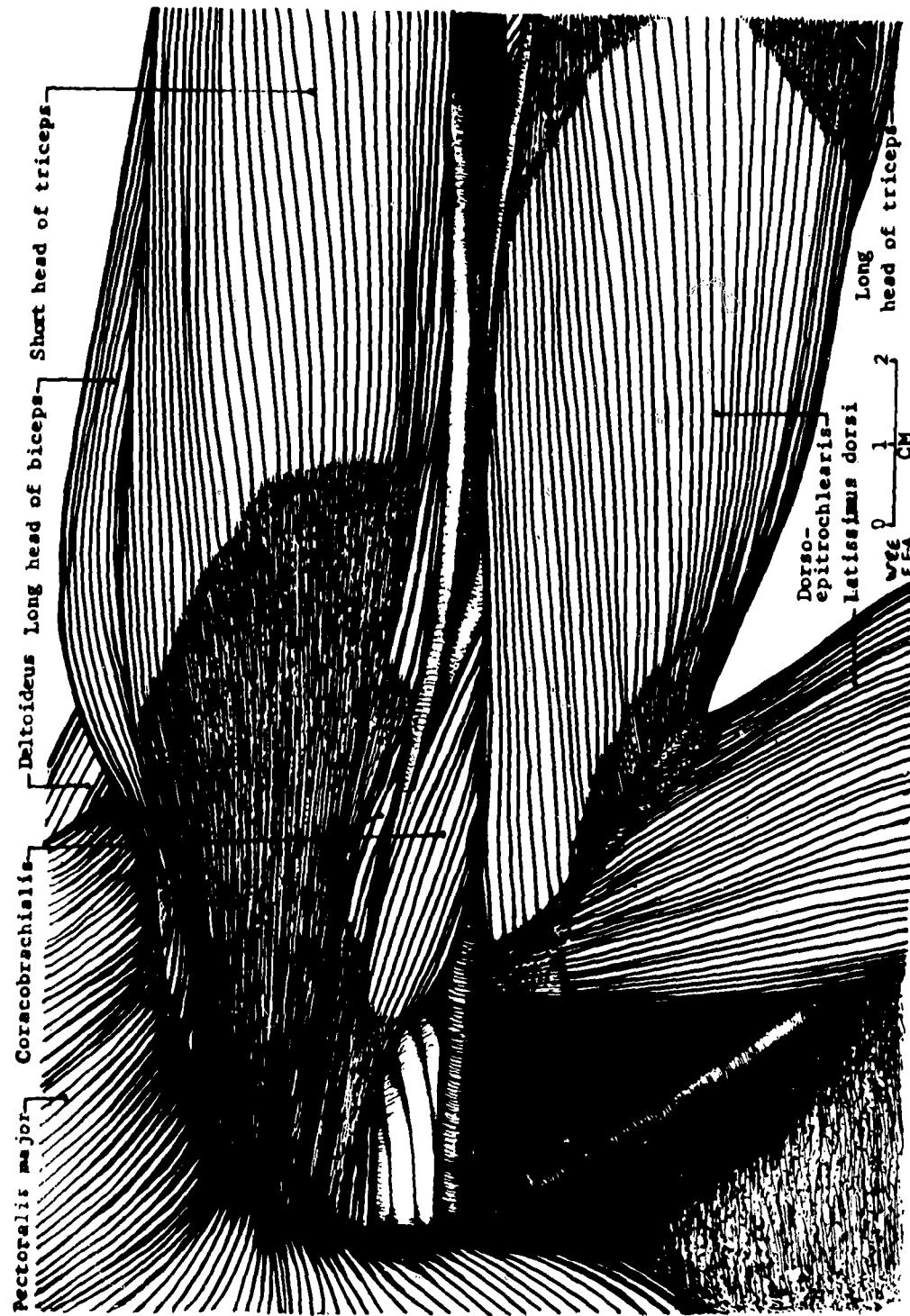


Figure 6

Anterior View of Left Axilla with Dermis Removed

Note pectoralis major is pulled up and back to reveal the brachial plexus and surrounding structures.

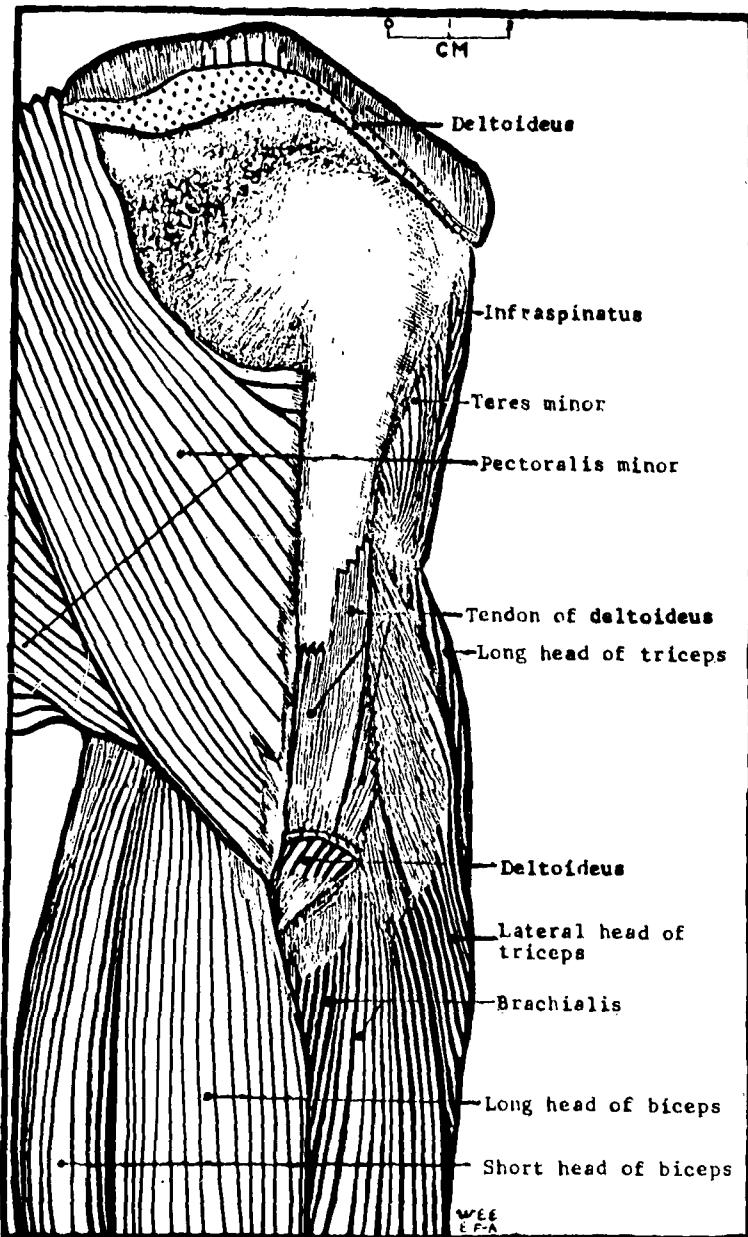


Figure 7

Anterolateral View of Left Shoulder after Removal of Deltoides

Note that the fleshy portion of deltoideus has been transected near the origin and near the insertion. The anterior three-fourths of the deltoideus tendon of insertion depicted proximal to the distal transection of the fleshy muscle is firmly adherent to the underlying humerus; this tendon is shown transected approximately at the proximal boundary of its extensive area of adherence to the bone.

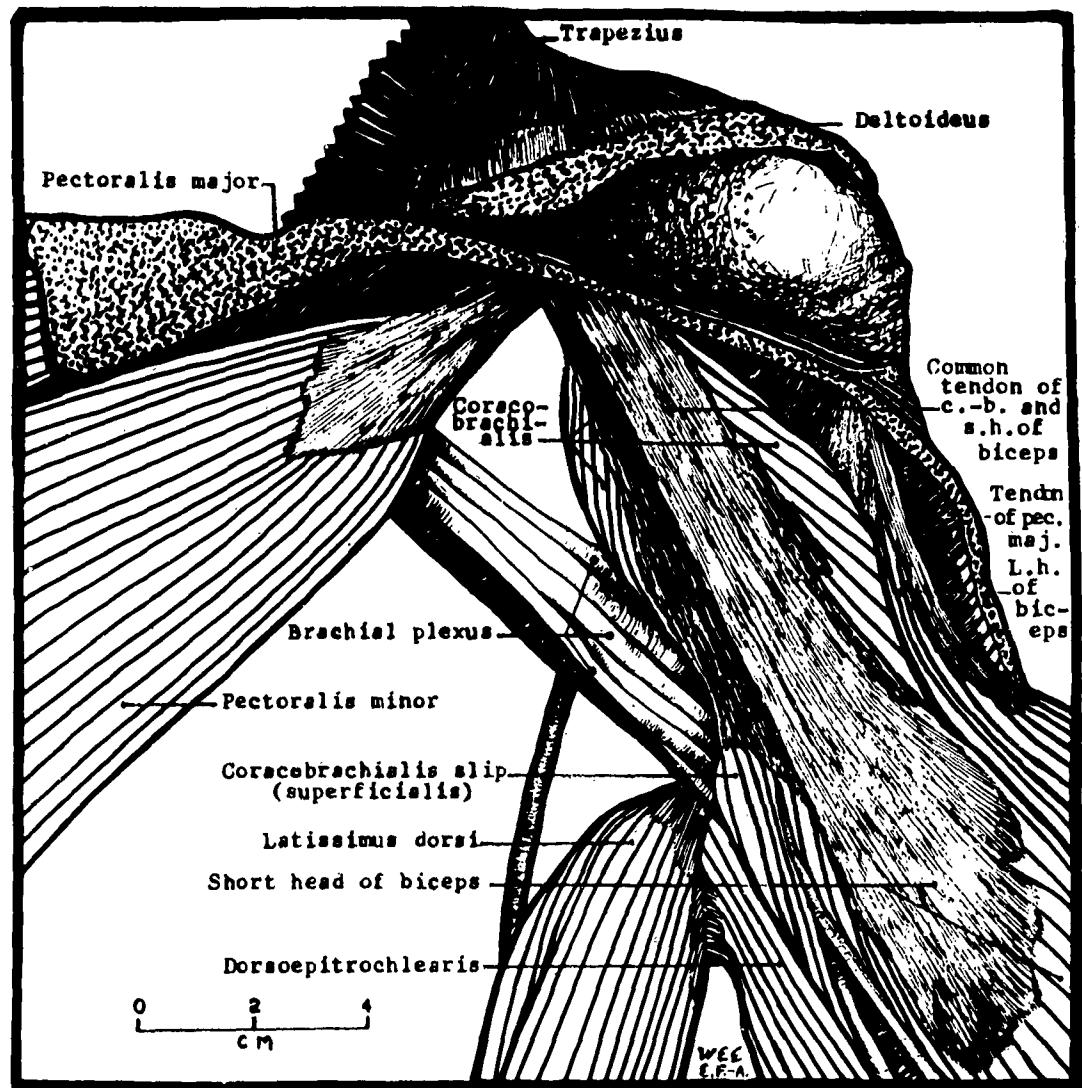


Figure 8

Anterior View of Deeper Musculature of Left Shoulder Area

Note that the removal of all but the fringing portions of deltoideus and pectoralis major presents to view pectoralis minor and the more proximal portions of the long head of biceps, coracobrachialis, and the brachial plexus.

The middle portion of sectioned pectoralis major is attached to bone only by relatively thin connective tissue, which thus does not constitute an effective area of origin or insertion.

Note that on either side of the broad common tendon of biceps and coracobrachialis are markedly thinner layers of tendon attached to the underlying superficial muscle surface and assignable to coracobrachialis alone.

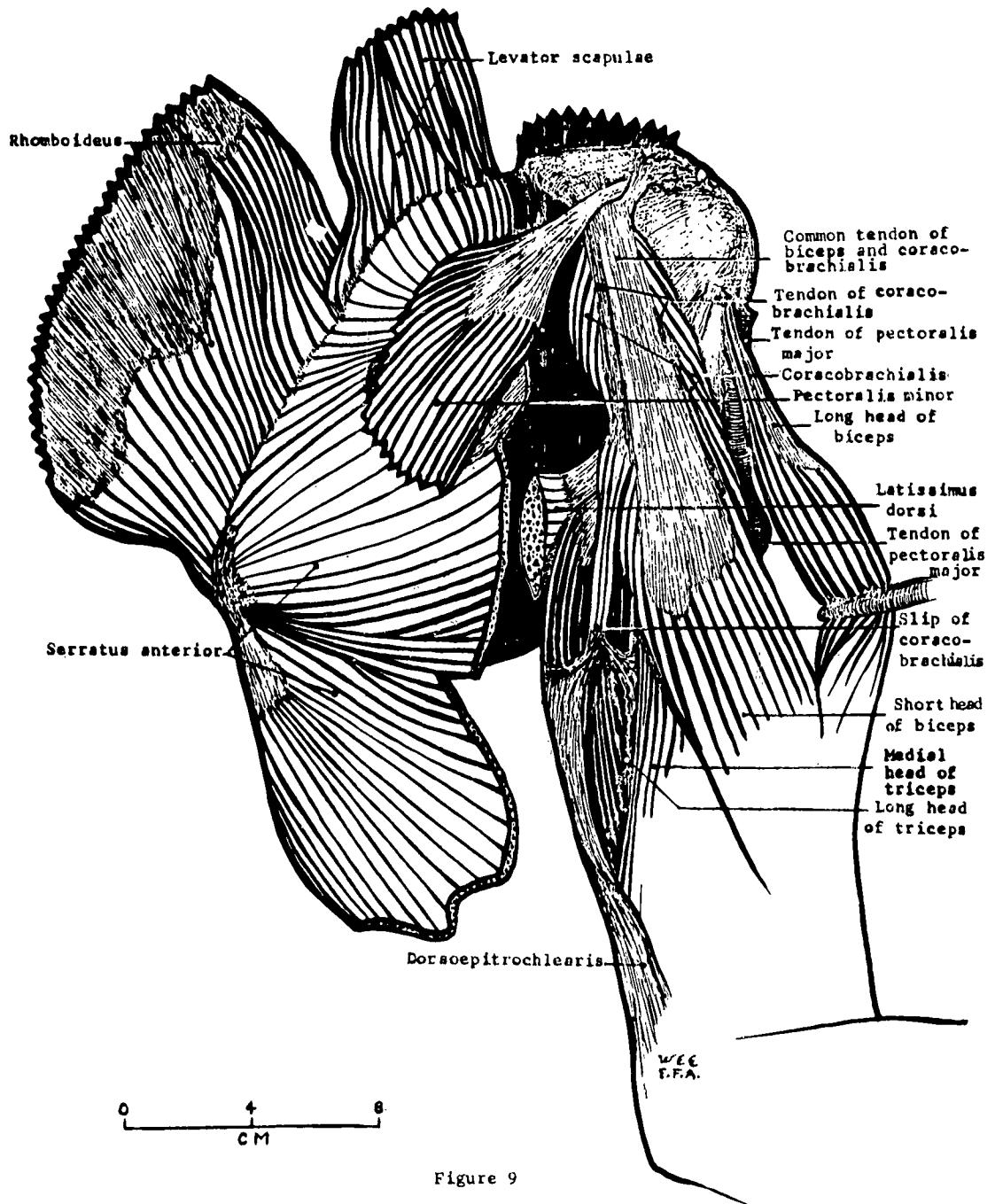


Figure 9
Anterior View of Musculature of Left Scapula and Brachium

Note that except for the moderate distortion to reveal the separation of the two heads of biceps, and the separation of dorsoepitrochlearis from triceps to reveal the insertions of the superficial slip of coracobrachialis into the fascia of dorsoepitrochlearis and on either side of the sulcus between the medial and long heads of triceps, all muscles are shown in fairly natural position, although the rib-cage, normally intervening between the deep surfaces of pectoralis minor and serratus anterior, has been removed.

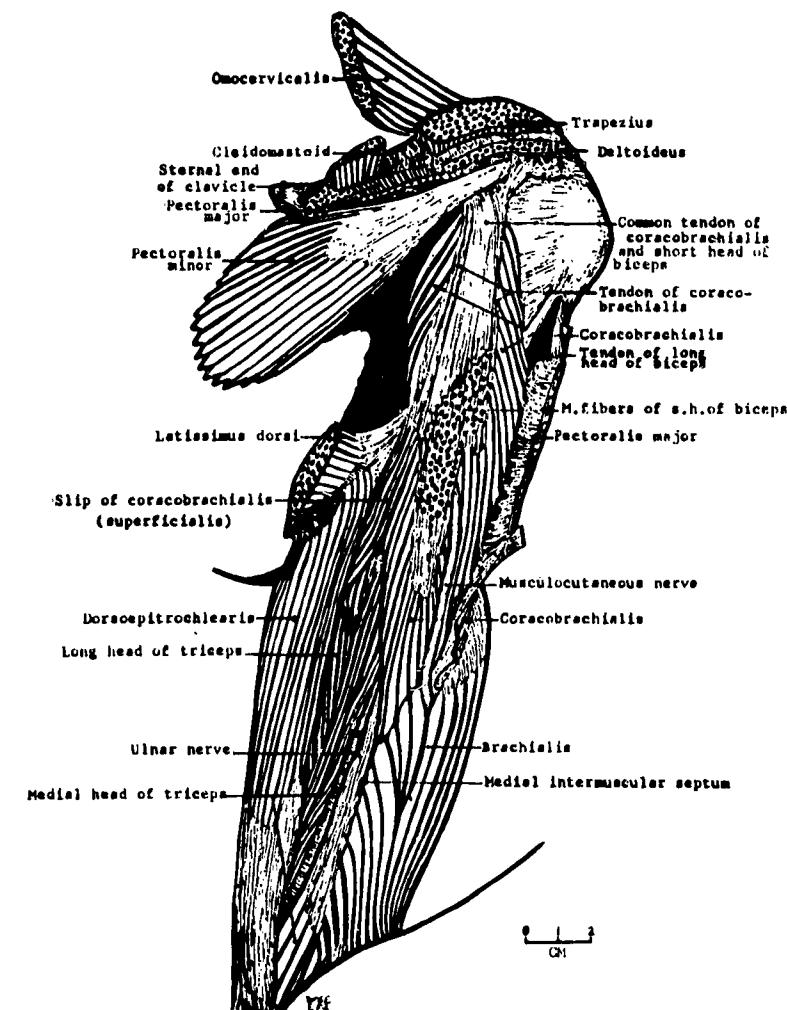


Figure 10

Anterior View of Left Scapula and Brachium, with Pectoralis Major, Deltoides, and Biceps Removed

Note trapezius, pectoralis major, and deltoides are all sectioned very near the clavicle (and acromion).

Note that the tendon of insertion of pectoralis major reveals, where sectioned, a thin layer of fleshy muscle fibers between the superficial and deep tendon layers.

Note that some brachialis fibers extend beyond the majority medially, arising from the superficial portion of the tendinous sheet which on its lateral border constitutes the weakly developed medial intermuscular septum, between brachialis and the medial head of triceps.

Note that the very thin band shown along the superior edge of the lateral portion of the clavicle represents the superior border of subclavius.

Note, at the proximal end and just beyond the distal end of the tendon of insertion of pectoralis major, the area of humerus covered only by fascia or extensions of tendons.

Note the musculocutaneous nerve piercing coracobrachialis and entering brachialis through a foramen near its proximal border, as well as the ulnar nerve (shown transected) largely enclosed within a groove on the superficial surface of the medial head of triceps.

Note that the belly of the short head of biceps and its overlying tendon of origin have been excised, with minute fragments left adhering to the underlying tendon to which the belly was fused. This underlying tendon is only a portion of that covering much of the superficial portion of coracobrachialis and, although shared with biceps, is thus more properly assignable to coracobrachialis. The upper margin of the excised area is the biceps belly's proximal border, which therefore represents the line along which the united common tendon of coracobrachialis and of the short head of biceps bifurcates proceeding distally to produce the two tendon-sheets superficial to the two muscles.

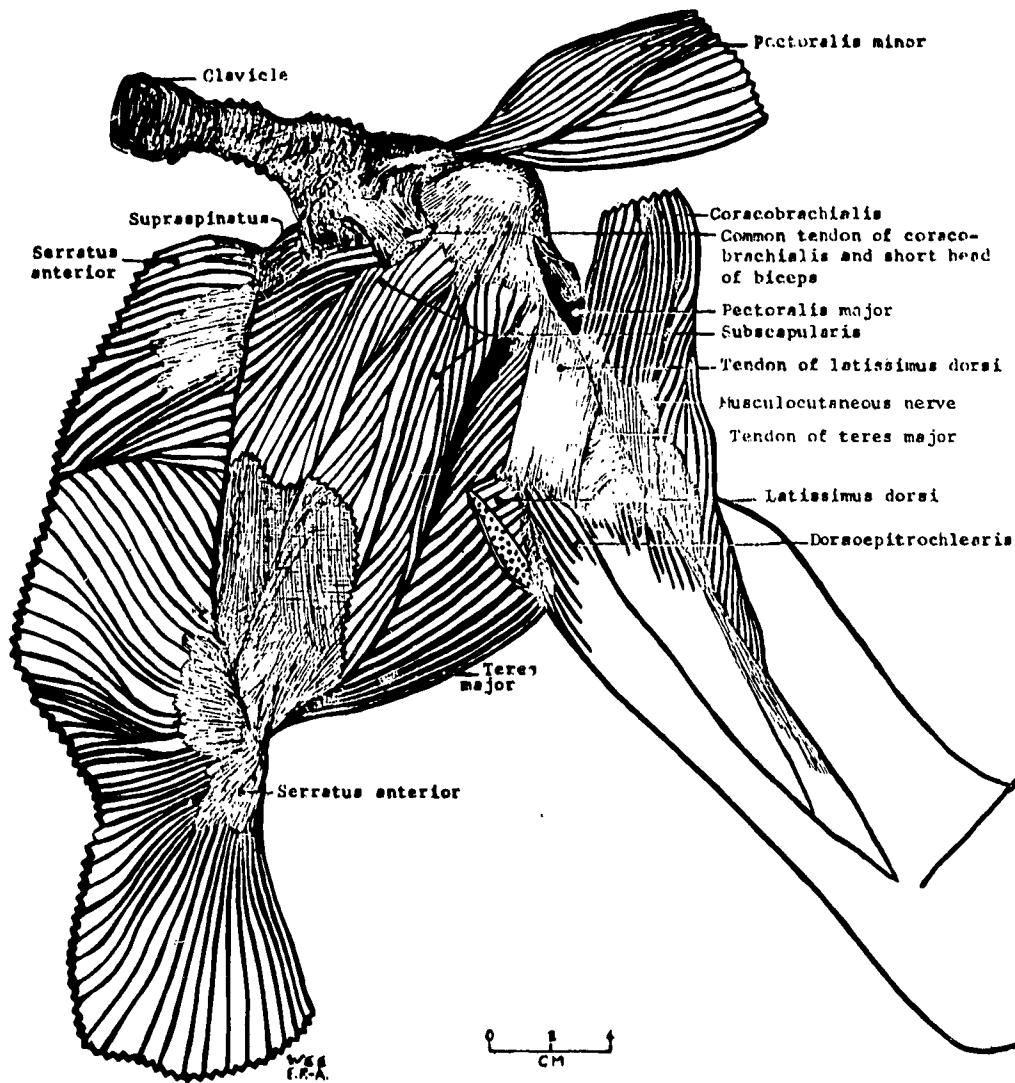


Figure 11

Anterior View of Left Scapular and Brachial Musculature, with Biceps Removed and Coracobrachialis and Serratus Anterior Transected and Displaced to Expose Underlying Structures

Note the marked distinction between the smaller superior portion of serratus anterior and the remainder and the lack of parallelism of its muscle fibers at the level of the inferior angle of the scapula.

Note that most of the thin fascial covering (with multidirectional fibers) of subscapularis has been removed and that the muscle fibers of each segment of subscapularis manifest marked non-parallelism.

Note the fold traversing the posterior surface of pectoralis minor and separating the two portions of markedly differing alignment.

Note that the deep surface of coracobrachialis reveals a fairly extensive tendon of insertion absent from the superior surface; at the border of this tendon the muscle is pierced by the musculocutaneous nerve, which aids in marking the separation between the brevis and the medial portions, with differing muscle fiber alignment.

Note that the section through the common tendon of origin of coracobrachialis and the short head of biceps reveals very thick tendon, occupying some 40 per cent of the total mass at that level (Figure 19, K-L provides a more detailed view).

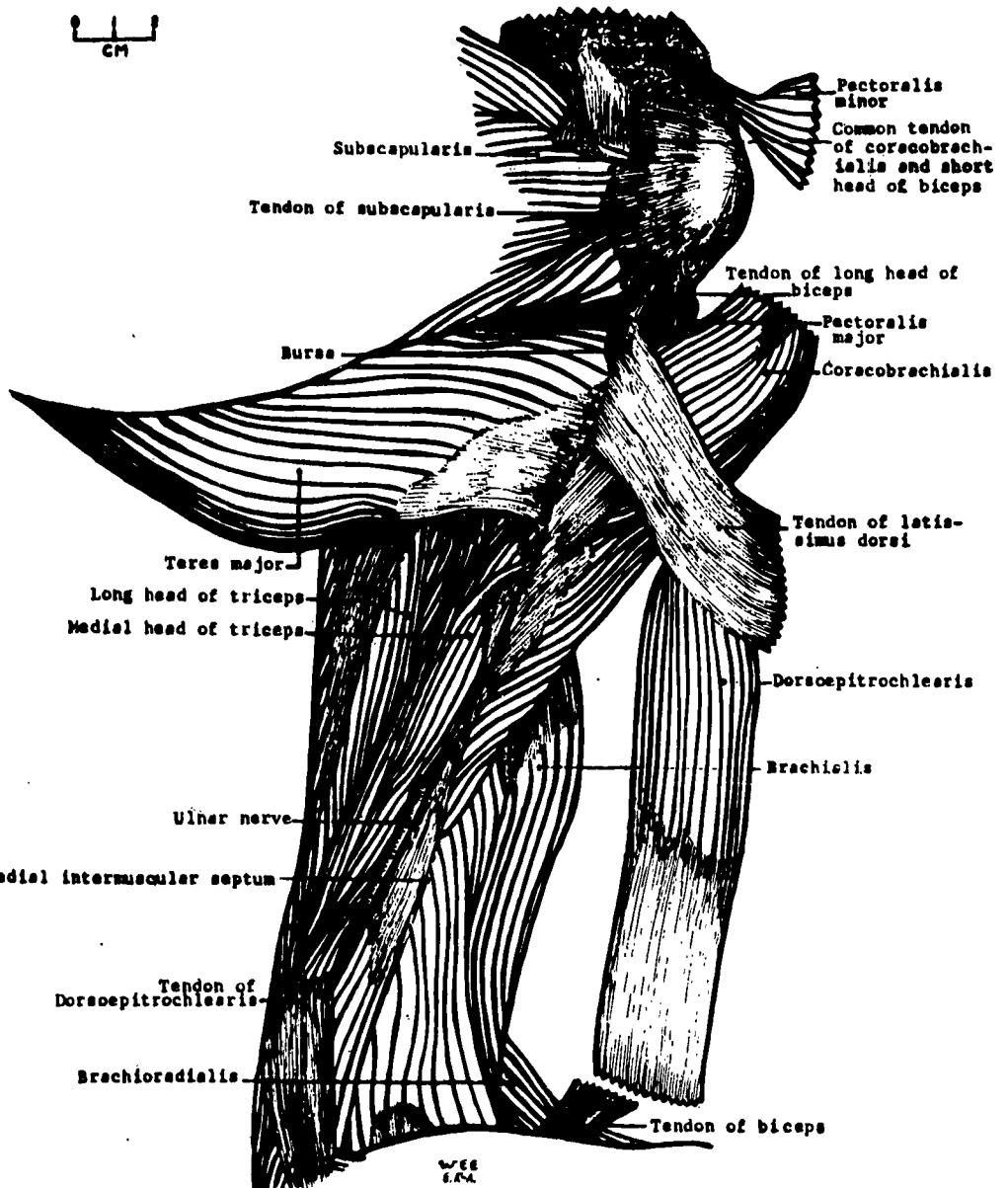


Figure 12

Anterior View of Left Arm, with Biceps Removed and Coracobrachialis and Dorsocepitrochlearis Transected and Displaced

Note the irregular tendon of insertion to teres major and the clearly developed bursa at the superior end of this insertion.

Note the relatively massive tendon of insertion of biceps, transected near the antebrachium.

Note the areas of exposed humerus immediately proximal to the superior border of teres major, deep to the tendon of origin of the long head of biceps, underlying the bursa, and between the medial head of triceps and brachialis at the most distal portion of these muscles shown.

Note that the view of the brachium is anteromedial, because the upper extremity is flexed at the elbow and rotated, as in Figures 9-11.

Figure 13

Section of Trapezius

Total length of section shown is 203 mm. Thickness at A is 26 mm., at 26 mm. lower is 27 mm., at 17 mm. lower still is 10 mm., and at successive 20 mm. intervals below that 8, 8, 7, 7, 7, 6, and 5 mm. (the last at 20 mm. above B).

Figure 14

Section of Latissimus Dorsi

Total length of section shown is 186 mm. on the superficial periphery, plus an estimated 10 mm. at the anterior end (dotted). Thickness 6 mm. below C is 3 mm., and at successive 20 mm. intervals below that 8, 13, 19, 20, 18, 21, 16, 10, and 7.5 (the last at the end of the extant section), measured perpendicular to the superficial surface.

Figure 15

Section of Deltoideus

This lateral view of the left deltoideus depicts the muscle with X the anteromedial and Y the posteromedial extreme points of origin, with Z the distalmost tip of insertion. Along their curved borders on the superficial surface, X to W is 85 mm.; W to Y, 125 mm.; X to Z, 192 mm.; Y to Z, 206 mm.; W to Z, 197 mm.; Z to E, 119 mm.; Z to V, 109 mm.; and Z to F, 89 mm. Along the deep surface, E to F is 101 mm. At 10 mm. along this deep surface from E and perpendicular to it (Fig. 15A), the muscle is 15 mm. thick; at 35 mm. (immediately lateral from the anterior surface of the shaft of the humerus), 20 mm.; at 65 mm. from E (immediately lateral from the posterior surface of the humerus), 27 mm.; and at 85 mm. from E (16 mm. from F), 21 mm.

Figure 16

Section of Pectoralis Major

This is the major section of the muscle resulting from autopsy, as shown in Figure 1; this section is shown as viewed from below, with the deep surface at the bottom of the outline. With a straight-line length of 85 mm., pectoralis major becomes steadily thicker from the medial border (G) to 13 mm. at 18 mm. distance, 19 mm. at 32 mm., 22 mm. from 42 to 61 mm., and, in the final 24 mm. to H, becomes abruptly thinner.

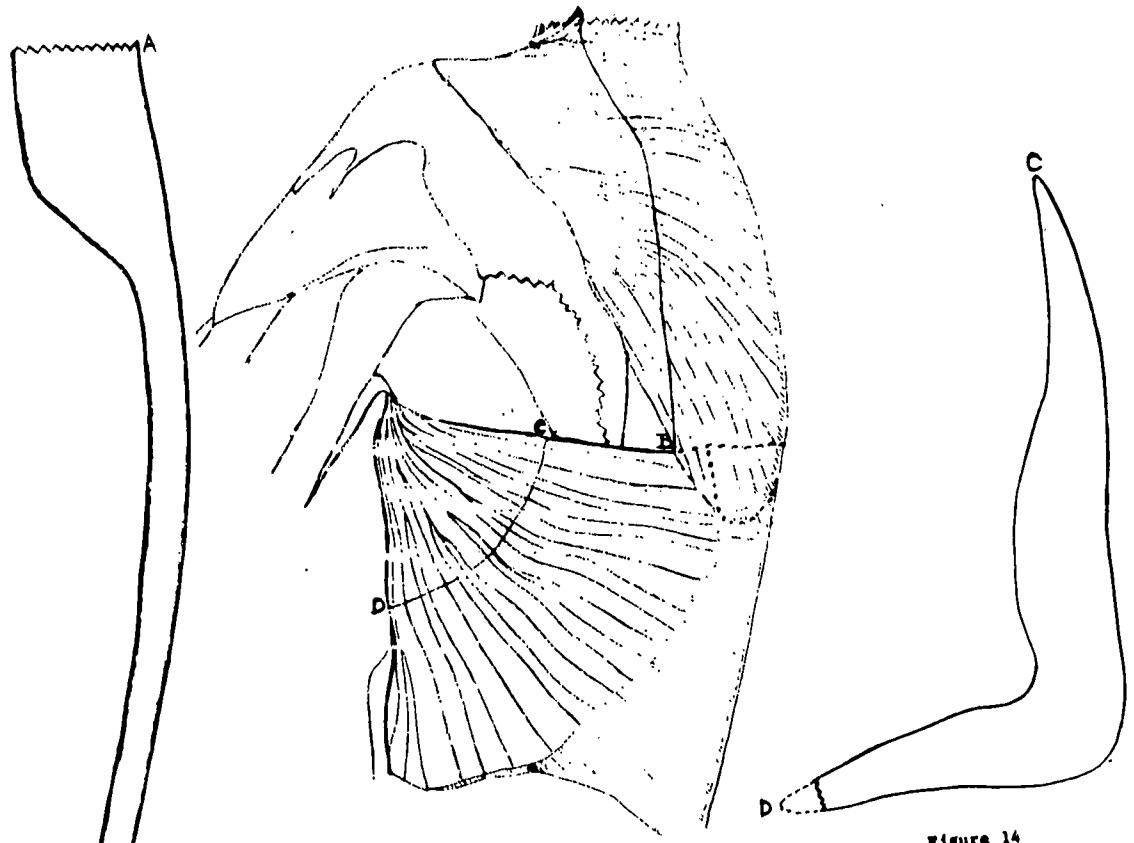


Figure 14

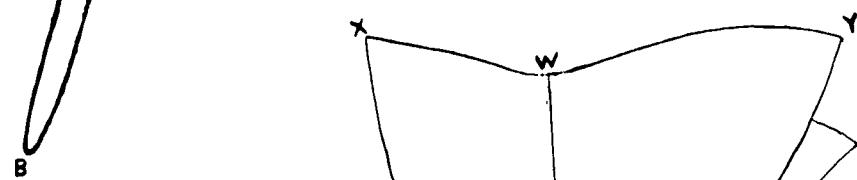


Figure 15

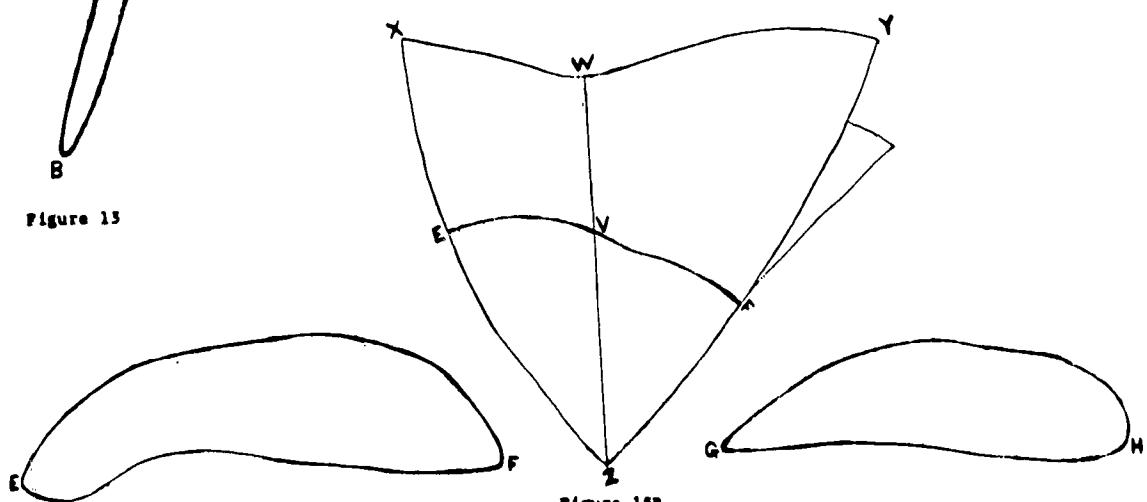


Figure 15A

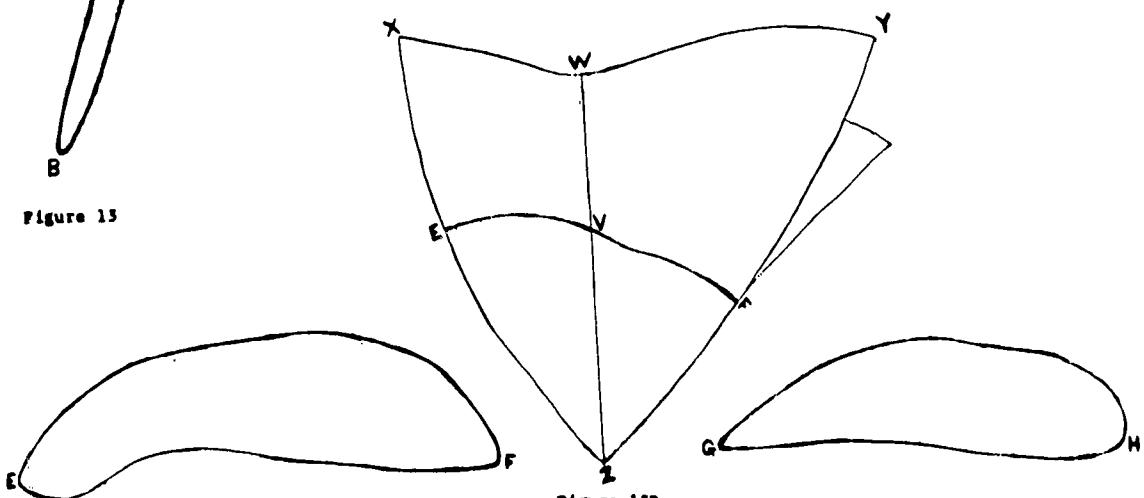


Figure 15B

Figure 16

W.E.C.

Scale for Figures
13, 14, 15A, 16

0 1 2 CM

Figure 17

Outline and Cross-Sections of Biceps

Biceps is here outlined as transected in Figures 10 and 12. The tendon shown is that appearing on the superficial surface, while dashed lines indicate the boundaries of tendons appearing on the deep surface -- and the extent of cleavage between the two heads on the deep surface.

The cross-sections -- with A-B, O-P, and Q-R enlarged two times unidimensionally relative to the others -- show the superficial (ventral) surface above. The unfilled strips and areas represent tendon.

The weight of the muscle in 1963 was 132.5 gm., plus 3.0 gm. estimated for the distal insertion (mainly tendon) and 0.4 gm. for the origin of the long head, not included in the excised portion.

Figure 18

Outline and Cross-Sections of Dorsoepitrochlearis

The four cross-sections are enlarged two times unidimensionally relative to the drawing of the entire muscle. Section A-B shows a continuous sheet of tendon across the deep surface, 0.8 mm. thick at A and gradually thinning to 0.6 mm., 1.5 mm. from B. A second sheet of tendon at A (beneath latissimus dorsi) extends slightly beneath the posterior border of dorsoepitrochlearis and is separated by a thin sheet of fleshy muscle tissue, with a total thickness for both tendons and muscle of 2.5 mm. at A, with an additional 4.0 mm. thickness of muscle above these three layers. Comparable measurements at the juncture of the two muscles are 2.0 mm. and 1.2 mm.

Section C-D, 31 mm. wide and 10 mm. thick, manifests no tendon. Section E-F, 35 mm. wide and 4 mm. thick, has a quite thin layer of tendon (c. 0.15 mm.) across the deep surface and extending 2 mm. past the anterior border (at F) on the superficial surface. Section G-H, at the widest point on the muscle (35 mm.), shows only tendon, 0.25 mm. thick 2 mm. from G to 0.5 mm. thick at the center to 0.8 mm. thick 8 mm. from H to 0.6 mm. thick 3 mm. from H.

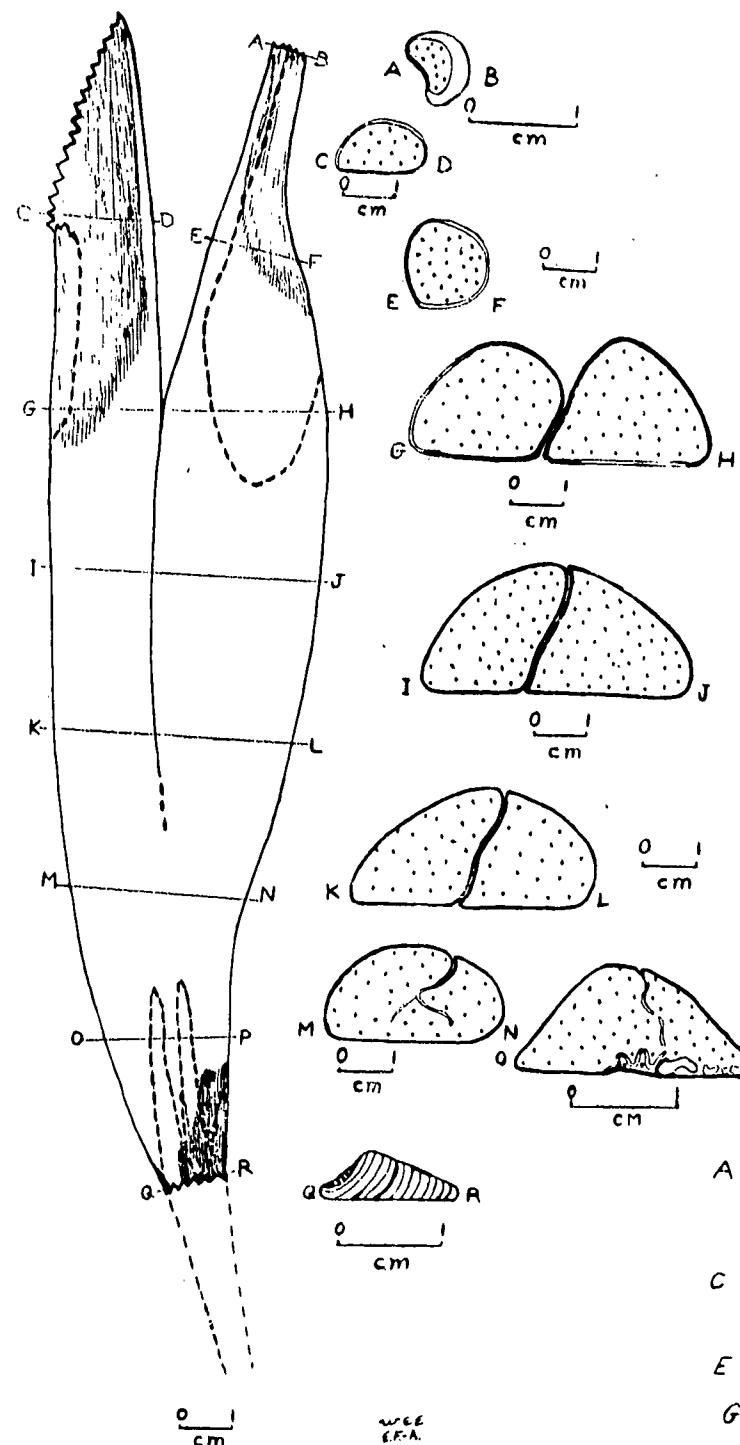


Figure 17

Outline and Cross-Sections of Biceps

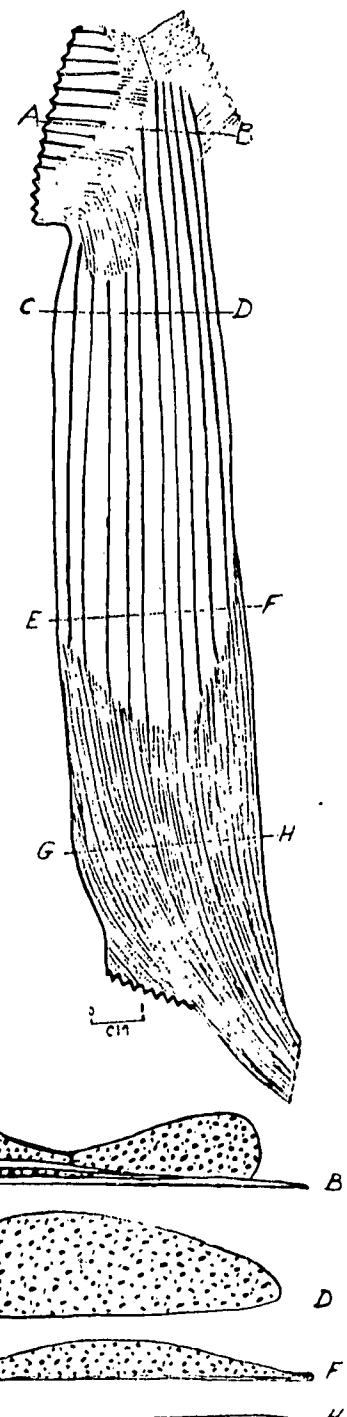


Figure 18

Outline and Cross-Sections
of Doroepitrochlearis

Figure 19

Outline and Sections of Coracobrachialis and Adjacent Muscles

In the upper left corner is outlined the 1.11 gm. superficial slip of coracobrachialis, with section A-B (8.9 mm. x 1.3 mm. average thickness), C-D (9.2 mm. x 1.4 mm.), and E-F (8.3 mm. x 0.95 mm.).

The outline in the upper right shows the location of section G-H (22.8 mm. wide and tapering from 1.1 mm. thick near the superior border, G, to 0.9 mm. in the middle and 0.6 mm. at 1 mm. from H) perpendicularly through the tendon of insertion of latissimus dorsi, 45 mm. from the humerus insertion on the superior and 28 mm. on the inferior border. Section I-J was taken, as indicated, near the origin of dorsoepitrochlearis. The central outline depicts the location of the four remaining sections: K-L through the common tendon of origin of coracobrachialis and the short head of biceps, 4 mm. distal to the tip of the coracoid process; M-N through the common tendon, coracobrachialis, the humerus, and the tendon of insertion of pectoralis major (at N); O-P through coracobrachialis (with the slip removed), the short head of biceps, and the musculocutaneous nerve; and Q-R through teres major and its tendon (at the bottom near Q), latissimus dorsi and dorsoepitrochlearis and their tendons, the slip of coracobrachialis, coracobrachialis, the musculocutaneous nerve, the short head of biceps, the humerus, and the tendon of pectoralis major enveloping the attenuated fleshy portion of that muscle.

In all sections, the deeper surfaces are represented at the bottom.

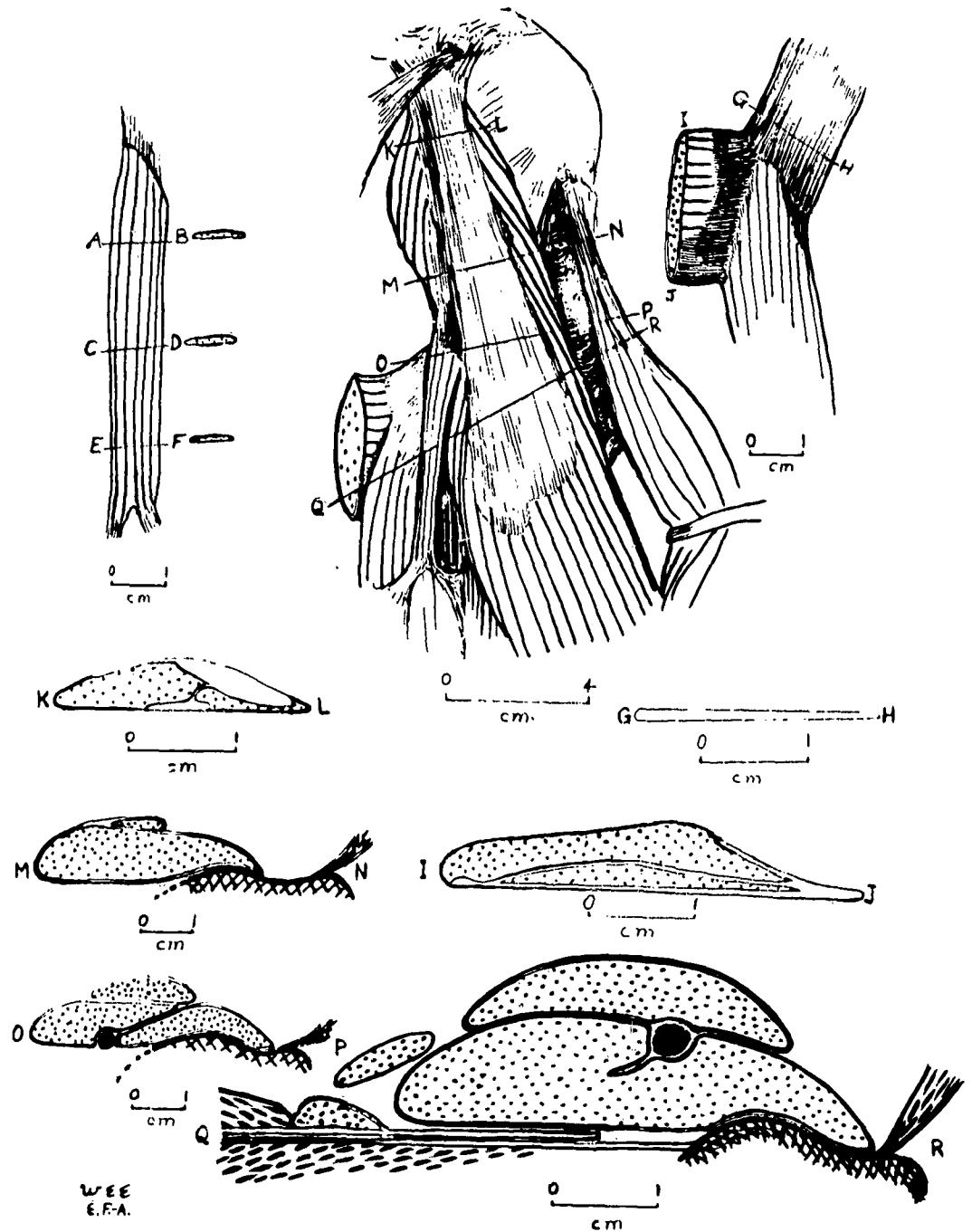


Figure 19
Outline and Sections of Coracobrachialis and Adjacent Muscles

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13. ABSTRACT

The left thoracic and brachial musculature of a young-adult female chimpanzee is described and illustrated with the accuracy of detail plus clarity made possible by the photo-etching process. Other data are depicted graphically by section drawings. Comparisons with data from the literature on other chimpanzees, apes, humans, and non-hominoid primates are also provided, with emphasis on quantitative aspects.

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14. **KEY WORDS:** Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

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